PB-221 376

POLLUTION AS A RESULT OF FISH CULTURAL ACTIVITIES

Russell N. Hinshaw

Utah State Division of Wildlife Resources

Prepared for:

Environmental Protection Agency

February 1973

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

EPA-R3-73-009
FEBRUARY 1973

Ecological Research Series

W73-11077

PB 221 376

Pollution As A Result of Fish Cultural Activities

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

Office of Research and Monitoring
U.S. Environmental Protection Agency
Washington, D.C. 20460

217

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Monitoring, Environmental Protection Agency, have been grouped into five series. These five broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The five series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies

This report has been assigned to the ECOLOGICAL RESEARCH series. This series describes research on the effects of pollution on humans, plant and animal species, and materials. Problems are assessed for their long- and short-term influences. Investigations include formation, transport, and pathway studies to determine the fate of pollutants and their effects. This work provides the technical basis for setting standards to minimize undesirable changes in living organisms in the aquatic, terrestrial and atmospheric environments.

/ ✓

SELECTED WATER RESOURCES ABSTRACTS

INPUT TRANSACTION FORM

1. Report No.
2.
3. Accession No.
W 73-11077

4. Title
Pollution as a Result of Fish Cultural Activities, (all caps)

5. Report Date
6.
8. Performing Organization Report No.

7. Author(s)
R~~ussell~~ N. Hinshaw

9. Organization
Utah State Division of Wildlife Resources
~~1596 West North Temple~~
Salt Lake City, ~~Utah 84116~~

10. Project No. EPA Project 18050 EDH

11. Contract/Grant No.

13. Type of Report and Period Covered

12. Sponsoring Organization

15. Supplementary Notes
Environmental Protection Agency Ecological Research Series report ~~number~~, EPA-R3-73-009, February 1973. 209 p, 5 fig, 1 tab, 13 ref

16. Abstract

Fish hatchery activities have been suspected as a source of pollution. This study was undertaken to evaluate ~~this in~~ hatchery discharges in relationship to possible pollution.

A program of semi-monthly physical-chemical analysis was conducted for a year at six trout hatcheries. These determinations were taken at the hatchery inflow and outfall, the receiving water above and below the hatchery outfall.

Bottom fauna was sampled once a month during the summer and bi-monthly through the winter on selected stations in the receiving waters.

Flow data was recorded for the influent, effluent, and receiving waters.

There was no correlation between the pounds of food fed in the hatcheries and:

1) changes of chemical quality in the receiving waters;
2) changes in kinds and numbers of bottom fauna organisms in the receiving waters.

The analysis of samples revealed degradation of the water quality through every hatchery and in the receiving water. This degradation was beneficial from a fisheries standpoint but water quality and public health considerations may require cleanup before acceptable levels could be achieved. (EPA)

17a. Descriptors
Water pollution, *Fish hatcher~~y~~ies, Fish ~~culturing, Fish Hatchery Discharges~~, Water Quality, Public Health, *Fish management, Water quality standards, Outfall, Water pollution sources, *Benthic fauna

17b. Identifiers
*Trout hatchery, Pollution evaluation, Receiving waters, *Fish Cultural Activities, Water Quality Criteria, *Fish hatchery discharges

17c. COWRR Field & Group
05B, 05C, 08I

Copy available from GPO Sup Doc as EP1.23:73-009 $ 2.60 ; microfiche from NTIS as PB 221 3[illegible], $0.95.

18. Availability ✓

19. Security Class. (Report)
20. Security Class. (Page)
21. No. of Pages
22. Price

Send To:

WATER RESOURCES SCIENTIFIC INFORMATION CENTER
U.S. DEPARTMENT OF THE INTERIOR
WASHINGTON, D. C. 20240

Abstractor Russell N. Hinshaw
Institution Utah State Division of Wildlife Resources

*U.S. GOVERNMENT PRINTING OFFICE: 1973 514-155/301 1-3

EPA-R3-73-009
February 1973

POLLUTION AS A RESULT OF FISH CULTURAL ACTIVITIES

By

Russell N. Hinshaw
Utah State Division of Wildlife Resources
1596 West North Temple
Salt Lake City, Utah 84116

Project 18050 EDH

Project Officer

Dr. Donald A. Hilden
Office of Air and Water Programs
Environmental Protection Agency
Washington, D.C. 20460

Prepared for

OFFICE OF RESEARCH AND MONITORING
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Price $2.60 domestic postpaid or $2.25 GPO Bookstore

EPA Review Notice

This report has been reviewed by the Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ABSTRACT

Pollution as a Result of Fish Cultural Activities

Fish hatchery activities have been suspected as a source of pollution. This study was undertaken to evaluate this in hatchery discharges in relationship to possible pollution.

A program of semi-monthly physical-chemical analysis was conducted for a year at six trout hatcheries. These determinations were taken at the hatchery inflow and outfall, the receiving water above and below the hatchery outfall.

Bottom fauna was sampled once a month during the summer and bi-monthly through the winter on selected stations in the receiving waters.

Flow data was recorded for the influent, effluent, and receiving waters.

There was no correlation between the pounds of food fed in the hatcheries and:

1. changes of chemical quality in the receiving waters
2. changes in kinds and numbers of bottom fauna organisms in the receiving waters

The analysis of samples revealed degradation of the water quality through every hatchery and in the receiving water. This degradation was beneficial from a fisheries standpoint but water quality and public health considerations may require cleanup before acceptable levels could be achieved.

This report was submitted in fulfillment of Grant No. 18050 EDH between the Environmental Protection Agency and Utah Division of Wildlife Resources.

TABLE OF CONTENTS

Page

ABSTRACT iii

TABLE OF CONTENTS v

LIST OF FIGURES vi

INTRODUCTION 1

MATERIALS AND METHODS 3

RESULTS 5

KAMAS HATCHERY 7
  Discussion - Physical-Chemical and Bottom Fauna Results 9
  Conclusions 15

MIDWAY HATCHERY 16
  Discussion - Physical-Chemical and Bottom Fauna Results 18
  Conclusions 23

LOA HATCHERY 25
  Discussion - Physical-Chemical and Bottom Fauna Results 27
  Conclusions 31

WHITE TROUT FARM 32
  Discussion - Physical-Chemical and Bottom Fauna Results 34
  Conclusions 40

SPRINGVILLE - STATE AND FEDERAL HATCHERIES 41
  Discussion - Physical-Chemical and Bottom Fauna Results 43
  Conclusions 50

CONCLUSIONS 52

BIBLIOGRAPHY 53

APPENDIX A: Physical-Chemical Data 54

APPENDIX B: Statistical Analysis Data 151

APPENDIX C: Bottom Fauna Data 159

Preceding page blank

LIST OF FIGURES

Page

TABLE 1 Summary of Statistical Analysis 6

PLATE 1 Kamas Hatchery 8

PLATE 2 Midway Hatchery 17

PLATE 3 Loa Hatchery 26

PLATE 4 White Trout Farm 33

PLATE 5 Springville (State and Federal) Hatcheries 42

INTRODUCTION

The almost complete absence of literature on the subject indicates that the quality of hatchery effluents has not, generally, been considered a serious enough problem to warrant investigation. The primary emphasis of pertinent work has been on the effects of pollutants on fish, rather than the effects of fish cultural activities on other beneficial uses downstream.

There are over 600 State and Federal fish cultural stations currently operating in the United States. These hatcheries produce a minimum of 12 million pounds of trout annually. They utilize each year more than 41 million pounds of fish food of which almost 23 million pounds are offal, meats, fish and other organic material. The remaining 18 million pounds of feed are commercially prepared pellets or other dry feeds. If accurate data were available for private fish cultural enterprises, these totals would be increased substantially.

The pollution potential of such a large fish cultural program could have a decided effect on the quality of water receiving hatchery effluents. It is generally believed that, except in rare cases, fish cultural waste waters are unlikely to cause major immediate pollution problems. Chronic effects on smaller receiving waters, however, have received less attention and are little understood. Recent surveys in Utah associated with efforts to arrive at stream classification have indicated that pollution from this source is a possibility. Some deterioration of stream and reservoir habitat, with resultant impact on the fishery resources, are now suspected of having occurred as a result of long term release of hatchery effluents into these waters.

There are a number of factors associated with fish cultural effluents that have potential or known existing detrimental effects on the quality of the receiving waters, the aquatic habitat, and the fauna dependent upon that habitat. Most of these may be broadly grouped into three categories.

The first category includes pathogens and parasites passing from the hatchery into the natural waters. The close proximity in which the fish are held as part of the cultural activities facilitates transmission of diseases and results in frequent epizootics (Davis, 1956). To what extent the release of these pathogenic and parasitic forms into the receiving waters affects other fishes, aquatic fauna, and the existing ecosystem is largely unknown.

A second category is composed of chemicals and drugs employed to control either prophylactically or therapeutically, diseases and parasites within the hatchery. These are introduced into the water either directly or through fish food. Again, little is known of their effect upon the system of the receiving waters.

The third group of factors include those that contribute to chemical and/or physical change of water quality. Organic wastes from fish metabolic processes (Brockway, 1950), waste feed as well as algae and detritus from pond and raceway cleaning can in the process of decomposition reduce dissolved oxygen levels, increase biochemical oxygen demand (B.O.D.), carbon dioxide, ammonia, nitrate and nitrite levels. Particles of waste not broken down within the hatcheries add to the turbidity, suspended and settleable solid levels of the effluent, and, the completely degraded portions of the waste can elevate the total dissolved solid level. The larger suspended solids deposited in the slower moving reaches of receiving waters can build up sludge beds.

The first and second categories, although important to an understanding of the total effect of hatchery wastes on the aquatic habitat and organisms, are sporadic in nature. The third category of factors, however, are encountered almost continuously throughout a substantial portion of the year under normal hatchery operating procedures. They constitute the most suspect and possibly significant sources of pollution. This study was designed to determine the levels, periodicity and effects of these pollutants on receiving waters and on aquatic organisms.

METHODS AND MATERIALS

The hatcheries selected for this study include four Utah State Division of Wildlife Resource trout hatcheries located near the cities of Kamas, Midway, Springville, and Loa; a federal hatchery at Springville; and a commercial hatchery (White's Trout Farm) at Paradise, Utah. These six hatcheries were chosen because they represent a diversity of production levels, feeding programs, and operational practices.

The feeding programs of commercial hatcheries frequently differ from those of Federal and State hatcheries. The commercial hatchery studied used both a dry feed and a wet feed composed primarily of offal from commercially dressed fish, chickens, warm-blooded animals, and whole rough fish. The State and Federal hatcheries investigated fed a balanced diet of dry food pellets.

Concrete rearing ponds were periodically cleaned throughout the year in State and Federal hatcheries. Algae and other growths were detached during pond cleaning and with the flow-through character of the raceway system entered the effluent. In hatcheries which used dirt rearing ponds these problems were of a smaller magnitude because this type of pond was seldom cleaned.

To sample all phases of fish rearing, a bi-weekly sampling program was conducted during the period of November, 1968 through October, 1969. The specific sampling stations for each hatchery were designed to include (1) the hatchery inflow, (2) the hatchery effluent, (3) the receiving water above entry of the hatchery waste water, (4) the receiving water one hundred feet downstream and (5) the receiving water one thousand feet downstream. Due to the complexity of the water supply systems and outfalls in some hatcheries, the number of stations varies with each individual hatchery (see Plates 1, 2, 3, 4 and 5). At some hatcheries multiple inflows and outfalls were sampled.

Dissolved oxygen, pH, carbon dioxide, and temperature were determined every two hours to detect any significant changes during the day. For all other measurements composite samples in lieu of "grab" samples were used to encompass the daily period of operation at each installation. Each of these samples was comprised of four sub-samples collected at each station at 2-hour intervals, beginning at 9:00 A.M.

These composite samples were examined for levels of biochemical oxygen demand (B.O.D.), most probable number (M.P.N.) coliform, total hardness, methyl orange alkalinity, specific conductance, nitrate, nitrite, ammonia, settleable, suspended and total dissolved solids, and turbidity.

Ford Chemical Laboratory, Salt Lake City, analyzed the composite samples for B.O.D., M.P.N. coliform, ammonia, and suspended and total dissolved solids using procedures outlined in Standard Methods for the Examination of Water and Wastewater, 12th Edition. Settleable solids and specific conductance were also run using the "Standard Methods" procedure. M.O. alkalinity, total hardness, nitrites, nitrates, turbidity and dissolved oxygen determinations were run using the Hach Chemical Company DR-EL analysis kit. Carbon dioxide levels were determined using the method of Needham and Needham (1966) and hydrogen ion concentrations were determined using the Helige comparator.

Flow data were taken at each installation utilizing a Gurley current meter and cross sections or discharges over weirs. This was done to compare the volume relationships of the effluent and receiving waters. Accurate water measurements were difficult to obtain at some of the hatcheries since there were more than one source and/or outfalls. Also, the volume of flow increased throughout some hatchery systems.

The poundage of fish fed and the poundage of feed utilized at each installation were determined and compiled monthly throughout the study period.

Bottom Fauna

Bottom fauna collections were made monthly during the summer and bi-monthly through the winter from stations located above and below the point of discharge in the receiving water, and, where possible, from the hatchery water source. This combination of stations allowed an analysis of changes in the numbers and kinds of aquatic invertebrates present in the receiving waters below the point of discharge at each hatchery. The locations of bottom fauna stations were the same as those used for chemical analysis (see Plate 1 through 5) and are similarly numbered. Water velocity required the use of hand-screens for collecting bottom fauna in all hatcheries except Loa where a Surber square foot sampler was used.

In collecting the handscreen samples, a five or ten square foot area was disturbed, and the aquatic invertebrates captured. The Surber sampler was used to obtain three square foot samples at each sampling station. The organisms collected were then segregated, identified and counted.

Populations of aquatic invertebrates sampled at the stations above the point of discharge were compared with those of the receiving water from stations 100 feet and 1,000 feet downstream. These populations were classified as to "pollution tolerant" or "pollution intolerant" forms based on the kinds of organisms present and on percentage of increase or decrease of populations at each station.

RESULTS

Results of the various physical - chemical parameters are graphed in Figures 1 through 192, Appendix A. Each parameter has been separated into groups. The first grouping compares the source water to the hatchery effluent. The second grouping compares the receiving water above the hatchery outfall to the 100 and 1,000 foot stations below the outfall. Analysis of variance compared the receiving water above the outfall and the station 1,000 feet below the outfall. The results from the 100 foot station on the receiving water was omitted from the analysis. This station was located too close to the outfall for sufficient mixing of the effluent and receiving water. Appendix B contains the results of the statistical analysis, Tables 2 through 8. These results are summarized in Table 1, page 6. Bottom fauna results were also analyzed statistically, but because of insufficient samples these data were not usable.

The tabulated bottom fauna data are listed in Appendix C, Tables 8 through 24. These tables list the kinds and number of bottom fauna found at the stations on the receiving water. Bottom fauna results are graphed and contained in Appendix C, Figures 193 through 218.

- HATCHERY -

Parameter	Kamas	Midway	Loa	White	Springville State	 Federal #1	 Federal #2
M.O. Alkalinity	**	...	...	...	...	...	...
Total Hardness	**	...	...	...	...	...	...
Nitrate	...	...	...	...	...	...	...
Nitrite	**	*	**	...	*	...	**
Settleable Solids	...	**	*	...	...	...	**
Sp. Conductance	**	*	...	...	**	...	...
Turbidity	...	*	...	...	...	*	**
Ammonia	**	...	**	**	**	**	**
B.O.D.	**	...	**	**	**	**	**
M.P.N. Coliform	...	...	**	**	**	**	**
Susp. Solids	...	...	**	...	**	**	*
Total Dis. Solids	...	...	...	...	...	...	...
Dissolved Oxygen	...	...	**	**	*	*	...
pH	...	**	**	...	...	...	...
Carbon dioxide	...	*	**	**	**	**	**
Temperature	*	...	...	...	...	...	...

* Indicates significance at the 95% confidence interval.
**Indicates significance at the 99% confidence interval.

Table 1. Summary of Statistical Analysis of Variance on the Receiving Waters Above and Below the Hatchery Effluents

KAMAS HATCHERY

Plate 1 (page 8) shows physical layout and positions of the various sampling stations. Stations 1 and 2 were located at the source springs for the hatchery house and raceways. Station 3 was at the outfall just above entry to the receiving water, Beaver Creek. Comparison of the springs with the outfall revealed the impact that the hatchery had on the spring water.

Three stations were located on the receiving water. Station 4 was located above the outfall on Beaver Creek. Stations 5 and 6 were located 100 feet and 1,000 feet below the outfall, respectively. Comparison of station 4 with stations 5 and 6 indicated changes in chemistry and bottom fauna due to the effluent from the hatchery.

Physical-chemical relationships are illustrated in Figures 1 through 32, Appendix A. Statistical analysis data is recorded in Table 2, Appendix B. Bottom fauna results are listed in Tables 9 through 11 and Figures 193 through 196, Appendix C.

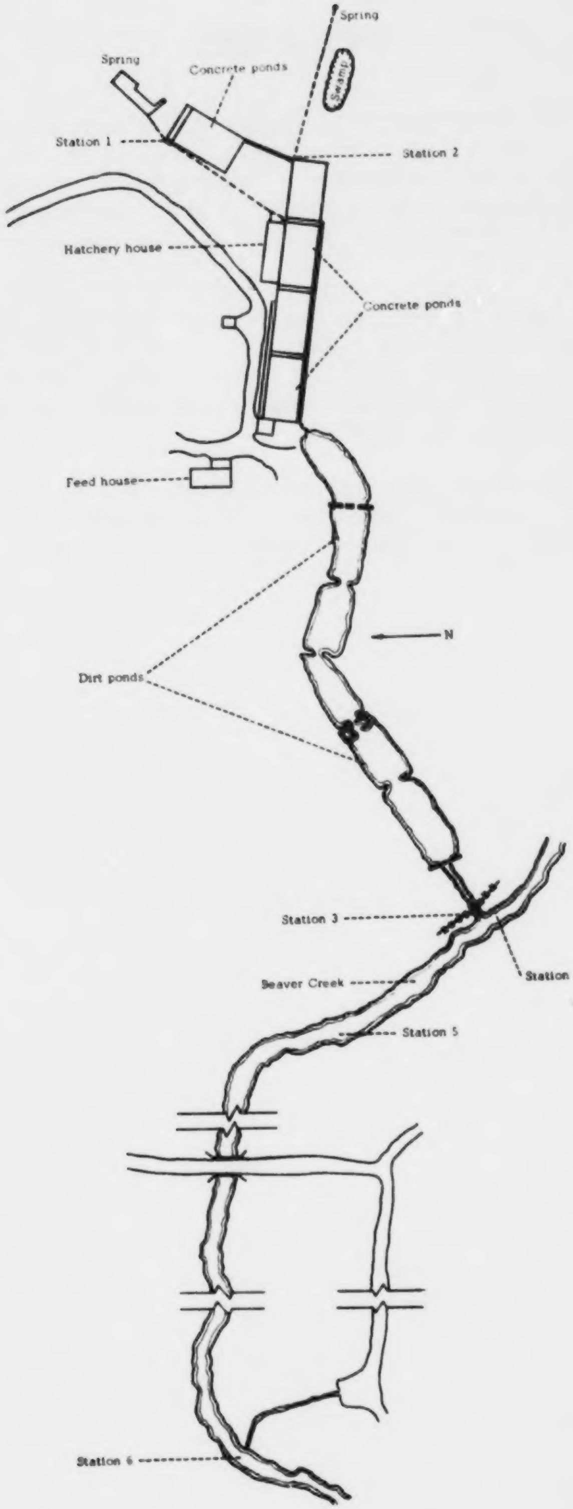
Spring
Spring
Concrete ponds
Swamp
Station 1
Station 2
Hatchery house
Concrete ponds
Feed house
N
Dirt ponds
Station 3
Station 4
Beaver Creek
Station 5
Station 6

Plate 1. Kamas Hatchery and Beaver Creek showing sampling stations.

Discussion - Physical-Chemical and Bottom Fauna Results

Methyl Orange Alkalinity

M.O. alkalinity values for Kamas hatchery, stations 1, 2, and 3, indicated no change except a slight decrease during the spring runoff, (Figure 1). The influence of spring runoff was demonstrated by a lowering of values in the receiving water, stations 4, 5, and 6 (Figure 2). Values at station 4 averaged 48 mg/l and concentrations increased at stations 5 and 6 as the water traveled downstream. There is a significant increase in M.O. alkalinity by the addition of the hatchery effluent (Table 1). This increase was due to the quality of the source water and not the result of hatchery activities.

Total Hardness

Hardness values (Figures 3 and 4) were affected by the spring runoff similar to the alkalinities. There was no change in hardness due to fish propagation activities on the waters through the hatchery. For the receiving water, hardness at the clean water station (4) averaged lower than stations 5 and 6, which increased to an average of 29 and 97 mg/l respectively. The addition of the effluent increased the total hardness significantly at the 99% confidence interval in Beaver Creek (Table 1); however, this change was not the result of hatchery activities.

Turbidity and Settleable Solids

Turbidity increased in the hatchery as well as settleable solids (Figures 7, 8, and 5, 6) respectively. When the water from the hatchery was added to Beaver Creek, concentrations of settleable solids and turbidity were increased. This addition resulted in the receiving water concentrations being raised 57% for settleable solids and 8% for turbidity over the original values for station 4 of 0.03 ml/l settleable solids and 14 Jackson Turbidity Units. Station 6 was located far enough downstream to allow some precipitation of these solids, resulting in lower concentrations of turbidity and settleable solids. Hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

Suspended Solids

Concentration of suspended solids at the source springs averaged 1.7 mg/l and were increased 28% through hatchery activities (Figures 9 and 10). Values at station 4 averaged 6.8 mg/l which were increased at station 5, by the addition of hatchery effluent. At station 6 suspended solids were even higher than at station 5. Hatchery activity based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

Total Dissolved Solids

Total dissolved solids concentrations (Figures 11 and 12) were increased 5% over the spring source average of 398 mg/l by hatchery activities. This water when added to the receiving water at station 4 which had an average concentration of 346 mg/l raised the values an average of 3%. Total dissolved solids were regularly higher at station 6 than at station 5. Hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus the receiving waters above and below the point of hatchery discharge were from the same population. (Table 1).

Specific Conductance

Specific conductance measured at the springs, stations 1 and 2, averaged 155 u mhos/cm. These readings remain relatively constant through the hatchery (Figure 13). When this effluent was added to Beaver Creek, the low conductance at station 4 (130 u mhos/cm) was increased 30% at station 5. Hatchery activity, based upon the 99% confidence interval significantly altered water quality. Thus, the receiving waters above and below the point of hatchery discharge were from different populations (Table 1).

Nitrate

Nitrate concentrations are depicted in Figures 15 and 16. The levels for stations 1, 2, and 3 (1.59 mg/l) were maintained through the hatchery and were added to the receiving water at this level. These concentrations increased the levels in the receiving waters about 22% above the 1.6 mg/l nitrate found at station 4. Hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

Nitrites

Nitrite (Figures 17 and 18) is a product of bacterial degradation on ammonia and organic substances and was more than doubled between the source and hatchery outfall. The source waters recorded average levels of 0.006 mg/l and the outfall a level of 0.016 mg/l nitrite. The nitrites introduced by the hatchery increased this product 33% in the receiving water at station 5. Low levels of nitrite at station 4 were increased at station 6. Hatchery activity, based upon the 99 % confidence interval significantly altered water quality. Thus, the receiving waters above and below the point of hatchery discharge were from different populations (Table 1). Bacterial degradation of ammonia and organic nitrogen products continued downstream, and this action has been reflected in nitrite levels which were higher in station 6 than in station 5. Nitrites oxidize readily to nitrates, and some correlation would be expected between these two anions. There were no discernible relationships to indicate that this was the case at this hatchery and its receiving waters.

Ammonia

Ammonia concentrations (Figures 19 and 20) at stations 1 and 2 averaged 0.21 mg/l. These were raised 34% in the outfall by the addition of fish excretory products and breakdown of organic nitrogen compounds. Some concentrations measured at the Kamas Hatchery were above those which are known to affect fish metabolism (Brockway, 1950). When these concentrations at station 3 were combined with those found at station 4 (0.24 mg/l) in the receiving water, the resultant levels were raised 27% at station 5. Comparison of station 4 with station 6 revealed that hatchery activity based upon the 99% confidence interval significantly altered water quality. Thus, the receiving waters above and below the point of hatchery discharge were from different populations (Table 1).

M.P.N. Coliform

M.P.N. Coliform bacterial counts (Figures 21 and 22) were increased ten fold through the hatchery over the average concentration in the source waters of 1600 bacteria/100 ml. An analysis of food has revealed as high as 60 M.P.N. coliform per gram and this increase through the hatchery may be related to this source. Beaver Creek counts, station 4, average over 61,000 coliform bacteria per 100 ml of water. This concentration was increased about 13% after the hatchery outfall was added, station 5. Concentrations at station 6 were higher than those found at station 4. However, hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of discharge were from the same population (Table 1).

Biochemical Oxygen Demand

Biochemical oxygen demand (B.O.D.) concentrations (Figures 23 and 24) averaged only 0.03 mg/l for the source springs. Adding food and waste products to the hatchery water increased B.O.D. 16 fold. The hatchery effluent, when combined with an average concentration of 3.3 mg/l B.O.D. of Beaver Creek at station 4, increased levels at station 5 21% and continued to increase downstream. Statistical analysis of the changes between the upstream receiving water, station 4, and the lower receiving water, station 6, showed that hatchery activity, based upon the 99% confidence interval, significantly altered water quality. Thus, the receiving waters above and below the point of hatchery discharge were from different populations (Table 1).

Dissolved Oxygen

Fish utilization reduced D.O. levels slightly through the hatchery (Figure 25). The addition of the hatchery effluent to Beaver Creek also reduced D.O. levels at stations 5 and 6 (Figure 26). However, the concentrations encountered were not decreased to levels which would be critical for fish propagation. Hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

Carbon Dioxide and Hydrogen Ion Concentration

Carbon dioxide concentrations were lowered throughout the hatchery, accompanied by a rise in pH (Figure 27, 28, and 29, 30 respectively). Reduction of carbon dioxide at the source springs to an average of 3.1 mg/l carbon dioxide at the outfall resulted from aeration over baffles in the raceways. The loss of carbon dioxide decreased the hydrogen ion concentration. The hatchery effluent has a minimal effect on the carbon dioxide content of the receiving water. Concentration of carbon dioxide remains essentially constant between stations 4 and 5, but continued aeration in Beaver Creek between stations 5 and 6 allowed additional carbon dioxide to escape into the atmosphere which resulted in a slight rise of pH at station 6. Changes in carbon dioxide and pH concentrations due to hatchery activities, and based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

Temperature

Water temperatures (Figures 31 and 32) through the hatchery remained within a range of 5°F. with no yearly fluctuations. However, Beaver Creek water varied from a low of 32°F. in the winter to a high of 63°F. in the summer. During the winter months the relatively warm water averaged 51°F. from the hatchery and was mixed with cold Beaver Creek water. The resultant difference was about 8°F. between stations 4 and 5. At the confluence of the hatchery effluent and Beaver Creek, there was an average difference of 20°F. The effluent did not affect the temperature of the receiving water as much during the balance of the year. The relatively warm hatchery effluent when added to Beaver Creek caused differences which were significant at the 95% confidence interval (Table 1).

Bottom Fauna

Bottom fauna was collected and later analyzed from stations 4, 5, and 6 on the receiving water of the Kamas Hatchery (See Plate 1 for layout). The substrate found at station 4 above the hatchery outfall consisted of fist-sized rocks to football-sized boulders. The shores were lined with willows about 8 feet high. No aquatic plant islands occurred in this area.

Station 5, located 100 feet below the outfall, had a similar rocky substrate; however, several aquatic plant islands have formed where silt and sludge precipitated around the base of the plants that formed the islands. Willows line the banks here also.

Station 6, located 1,000 feet below the outfall, had a substrate of small rocks but was similar to station 4; there were no islands of aquatic plants. The results of the bottom fauna analysis are contained in Tables 9, 10, and 11 and Figures 193 through 196 (Appendix C).

The water of Beaver Creek had concentrations of dissolved substances derived from mountains composed of Precambian quartzite. These mountains dissolve slowly in water, and the surface runoff and spring water from these sources are about as pure as distilled water. Consequently, the productivity of these waters is low and supports relatively few organisms. When dissolved materials like bicarbonate ions and nutrients, are added by the hatchery, growth of all organisms is enhanced (Figure 193). Pollution tolerant organisms increased 93%, and clean water forms increased 64% (Figures 194 and 196). Throughout this report the term "pollution tolerant organisms" designates those animals which are classified as Annelida, Gastropoda, and the Diptera family Chironomidae. These organisms can also be found in clean, unpolluted water but have the ability to live in heavily polluted environments.

In the case of the Kamas Hatchery there was a large increase of pollution intolerant organisms accompanied by a larger increase of pollution tolerant forms. This indicated that possible degradation of the water has occurred, but coupled with this increase there was an increase in number of kinds of organisms (Figure 195). The influence of the hatchery was believed to be one of beneficial enrichment.

Between stations 4 and 5, the kinds of organisms present increased from 18 to 22. The term "kind" refers to a group of organisms identified as belonging to a particular class, order, family, or genera. These are listed in the tables of results and retain their identity for the analysis of organisms collected at all the stations examined in this study. A reduction in kinds of organisms would be indicative of a deleterious situation.

An increase of 43% of clean water organisms and a decrease of 9% of the pollution tolerant organisms occurred between stations 5 and 6. Numbers of kinds increased from 22 to 24, indicating an improving situation.

Water Flows

Flows (cfs) were measured monthly throughout the sampling year and were highly variable. At times the measured volume at the outfall was less than the cumulative flows entering the hatchery system. Flows, even from the spring sources, were also highly variable. This discrepancy can be explained by measurement error in determining the source flows of hatchery water rather than water loss in the hatchery system. Because of this variability, the median of the range of flow from the springs, outfall and the receiving water was compared. The flows found at the outfall of the Kamas Hatchery was 1/3 as great as the receiving water.

Conclusions

Of the 16 tests, only carbon dioxide was upgraded. All other tests show a degradation of the water or remained unchanged. However, the influence on the receiving water chemistry by hatchery effluent generally was degrading.

An analysis of variance was conducted on the changes made by the hatchery waters on the receiving stream. Methyl Orange Alkalinity, total hardness, nitrite, specific conductance, ammonia, B.O.D. and temperature were increased significantly (Table 1). The hatchery source waters were originally different from Beaver Creek and many parameters were not increased by hatchery activities; however, hatchery use increased nitrite, ammonia and B.O.D. levels. When effluent was added to Beaver Creek there was a significant increase of these parameters in the receiving water. This enrichment increased food organisms for the fishery present.

Since the receiving water above the outfall was very low in nutrients necessary to support aquatic organisms, the effect of the Kamas Hatchery effluent on Beaver Creek was of beneficial enrichment improving the natural fish food habitat. The addition of bicarbonates from the springs supplying the hatchery and the nitrogenous compounds and other nutrients from the hatchery enhanced the growth of organisms in the stations below the outfall. The hatchery effluent increased the growth of individuals and kinds of bottom fauna in Beaver Creek. This increase is indicative of an enrichment situation, and not necessarily the degradation of the resource which actually depends on the increased food supply for survival.

Figure 197 shows the relationship of the food fed and the fish present for the year sampled. A comparison of this graph with the chemistry graphs shows no correlation between the amount of food fed and the fish present with the degradation of the water. There seems to be an inverse relationship that is believed to be caused by spring runoff and not any fact connected with fish cultural activities.

MIDWAY HATCHERY

Midway Hatchery (Plate 2) required seven stations for sampling. Stations 1 and 2 were the main sources for the hatchery water. Because of a high water table, large quantities of ground water seeped into the runs and ponds. For this reason the springs constituted only a part of the water supply. Stations 3 and 7 are located at the outfalls that flowed directly into the receiving water, Snake Creek.

Stations 4, 5, and 6 were located on Snake Creek. Station 4 was above the outfalls, and station 5 was 100 feet below. Station 6 was situated 1,000 feet below the outfall at the lower end of a pasture just above a railroad bridge.

Physical-chemical data is shown in Appendix A in Figures 33 through 64. Statistical analysis of variance is recorded in Table 3, Appendix B and bottom fauna findings are listed in Tables 12, 13, and 14 and Figures 198 through 202, Appendix C.

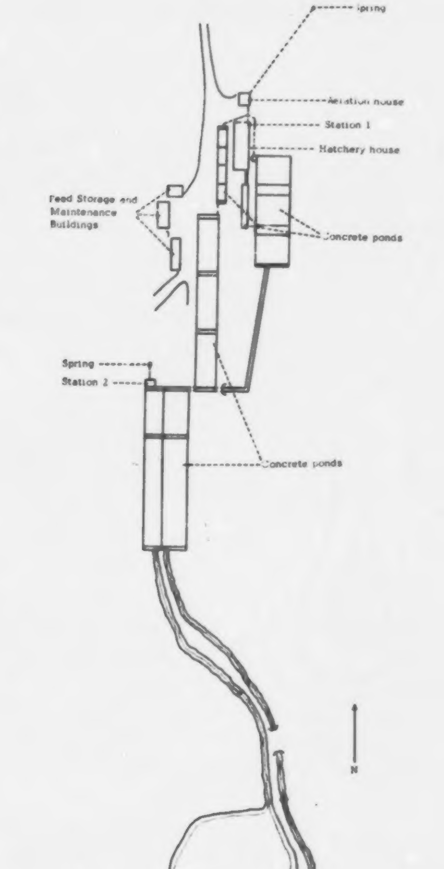
Spring
Aeration house
Station 1
Hatchery house
Feed Storage and Maintenance Buildings
Concrete ponds
Spring
Station 2
Concrete ponds
N
Dirt ponds
Snake Creek
Station 4
Station 7
Station 3
Pasture
Station 5
Station 6
Pasture

Plate 2. Midway Hatchery and Snake Creek showing sampling stations.

Discussion - Physical-Chemical and Bottom Fauna Results

Methyl Orange Alkalinity

M.O. Alkalinity (Figures 33 and 34) was reduced through Midway Hatchery. Station 1 was the primary source for hatchery outfall station 7, and the west spring station 2 formed the source for station 3 outfall. There was some crossflow in the hatchery runs plus considerable inflow of ground water. Station 2 spring had an average concentration of M.O. alkalinity of 345 mg/l. The concentrations at the other spring, station 1, and the outfalls station 3 and 7 were slightly lower. Mixing of the two outfalls with the receiving water, station 4 (282 mg/l), caused a very slight rise at stations 5 and 6. Hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of discharge were from the same population (Table 1). The receiving water showed a periodic reduction of M.O. alkalinity during the spring runoff.

Total Hardness

Hardness values (Figures 35 and 36) showed a slight reduction from 532 mg/l between stations 1 and 7, but no similar change was evident between stations 2 and 3. Hardness of 459 mg/l in the receiving water was not altered and hatchery activity based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of discharge were from the same population (Table 1). Dilution during spring runoff resulted in some periodic lower concentrations.

Turbidity, Settleable, and Suspended Solids

Turbidity throughout Midway Hatchery (Figure 37) was composed entirely of suspended solids (Figure 39) since there were no settleable solids (Figure 41) in the hatchery waters sampled. Station 4 on Snake Creek, above the outfall, had the highest average values for turbidity (13.5 Jackson Turbidity Units), suspended solids (8.3 mg/l), and settleable solids (0.1 ml/l), Figures 38, 40, and 42 respectively. Turbidity at station 4 was reduced to 1/3 that of station 5 after the addition of hatchery effluent. Turbidity increased 2 JTU between stations 5 and 6. A large reduction of turbidity at station 5 was probably the result of incomplete mixing. There was a significant decrease of turbidity based upon the 95% confidence interval between stations 4 and 6 (Table 1) which altered water quality.

Settleable materials were reduced as the receiving water passed from station 4 through station 6 resulting from slower velocities and an aquatic weed-choked streambed. Yearly runoff fluctuations were present but barely discernible. Changes in settleable solid concentrations due to hatchery activities, based upon the 95% confidence interval, significantly altered water quality while suspended solids were not significant at the same interval (Table 1).

Total Dissolved Solids

Examinations for total dissolved solids (Figure 43) of the source waters showed that the west spring, station 2, averaged higher TDS (694 mg/l) than the east spring, station 1 (678 mg/l). At low flows TDS values decreased, but with the increased flows of spring runoff the levels increased. The outfall from the hatchery averaged 686 mg/l TDS. When this water was added to the receiving water at station 4 (Figure 44) which had an average concentration of 683 mg/l, the values were decreased 3% at station 5. Again with mixing, the concentrations were higher at station 6 than at station 5. Hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of discharge were from the same population (Table 1).

Specific Conductance

Specific conductance measures concentrations of ionizable material in water. The average values of the springs, stations 1 and 2, were 1040 and 1230 u mhos/cm, respectively (Figure 45). These readings remained constant through the hatchery for the east system, stations 1 and 7, and was reduced through the west system stations 2 and 3 over 100 u mhos/cm. When this effluent was added to Snake Creek, the conductance at station 4 (921 u mhos/cm) increased 6% (Figure 46) at station 5. A slight reduction occurred at station 6; however, the change between stations 4 and 6 due to hatchery activities, based on the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1). No annual fluctuations were observed in the hatchery waters; but station 4 on Snake Creek was influenced strongly by spring runoff water. Concentrations at stations 5 and 6 remained stable, possibly because of the large quantities of highly conductive water introduced from the hatchery.

Nitrate

Nitrate concentrations are depicted in Figures 47 and 48. Levels for the source water averaged higher (3.71 mg/l) in nitrates than the effluent, stations 3 and 7 (3.32 mg/l). These concentrations increased the levels in the receiving waters about 18% above the 2.3 mg/l nitrate found at station 4. Concentrations of nitrate decreased between stations 5 and 6. Hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

Nitrite

Nitrite (Figures 49 and 50) is a product of bacterial degradation and was increased over 6 fold between the source and hatchery outfall. The source waters recorded average levels of 0.006 mg/l and the outfall averaged 0.037 mg/l nitrite. The effect of the concentrations of nitrites introduced by the hatchery effluent resulted in a 36% increase in the receiving water between stations 4 and 5. Further increases between stations 5 and 6 suggest that additional degradation of ammonia and organic compounds was occurring. Hatchery activity, based upon the 95% confidence interval, significantly altered water quality. Thus, the receiving waters above and below the point of hatchery discharge were from different populations (Table 1).

Ammonia

Ammonia concentrations (Figure 51) at stations 1 and 2 averaged 0.36 mg/l. These levels are increased 2 fold by the addition of fish excretory products and breakdown of organic nitrogen compounds. Levels at the outfall often exceeded values considered by Brockway (1950) to be detrimental to fish. When effluent, stations 3 and 7, were combined with those in Snake Creek, station 4, (0.84 mg/l), the resultant levels were raised 2% at station 5 (Figure 52). Between station 5 and station 6 the average ammonia concentrations increased 5%. Hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

MPN Coliform

Coliform bacteria counts (Figure 53) were increased 16 fold through the hatchery over the average concentration in the source waters of 5,720 bacteria/100 ml. Snake Creek counts at station 4 (Figure 54) averaged 54,000 coliform bacteria/100 ml of water. This concentration was increased 31% after the hatchery outfalls were added above station 5. Cattle pastured in the field below station 5 could be responsible for the 62% increase between stations 5 and 6. Hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

Biochemical Oxygen Demand

Biochemical oxygen demand (B.O.D.) concentrations (Figure 55) averaged 0.58 mg/l and 2.14 mg/l for stations 1 and 2, respectively. Adding food and fish waste products to the hatchery water supply increased B.O.D. 5 fold. The hatchery effluent, when combined with Snake Creek at station 4 (Figure 56) which had an average concentration of 5.46 mg/l B.O.D. increased levels 2.5% at station 5. B O.D. concentrations continued to increase downstream to station 6; however, hatchery activity, based upon the 95% confidence interval, did not alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1). The high B.O.D. levels in Snake Creek can possibly be attributed to organic wastes from summer homes and extensive livestock grazing throughout the valley.

Dissolved Oxygen

Dissolved oxygen (D.O.) concentrations (Figure 57) were increased 25% in the hatchery system by aerating baffles. Initial aeration was provided at the springs by converted diesel engine blowers. The addition of the hatchery effluent to Snake Creek reduced D.O. levels at station 5 (Figure 58). D.O. concentrations were not decreased to a level which would be critical for fish propagation. D.O. concentrations between stations 5 and 6 were enhanced by photosynthetic action of aquatic plants, and hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

Carbon Dioxide and Hydrogen Ion Concentrations

Carbon dioxide concentrations (Figures 59 and 60) were lowered through the hatchery, accompanied by a rise in pH (Figures 61 and 62). High average carbon dioxide levels of 29 mg/l and 56 mg/l were found at stations 1 and 2 respectively. As carbon dioxide was liberated to the atmosphere by aeration, the pH became increasingly alkaline. The hatchery effluent when combined with Snake Creek increased carbon dioxide 39% which in turn depressed pH 6% between stations 4 and 5. Concentrations of carbon dioxide and pH levels remained constant between stations 5 and 6. Hatchery activity, based upon the 95% confidence interval for carbon dioxide and the 99% confidence interval for pH, significantly altered water quality. Thus, the receiving waters above and below the point of hatchery discharge were from different populations (Table 1).

Temperature

Water temperatures (Figures 63 and 64) at the spring stations 1 and 2 varied only 6°F. throughout the year. Extremes occurred during the summer and winter at stations 3 and 7. The influence of hatchery effluent on Snake Creek water temperature was minimal because the water temperature in the hatchery system adjusted to that of the receiving water while transversing a series of long dirt ponds.

Bottom Fauna

Bottom fauna was collected and later analyzed from stations 4, 5, and 6 on Snake Creek, the receiving water, of the Midway Hatchery (see Plate 2 for layout.) The substrate found at station 4 above the hatchery outfall consisted of small gravel to baseball-sized rock. This material was composed of limestone which underlies the valley from outcroppings to about 15 feet below the ground surface. Willows border the stream providing shade and cover.

Station 5 was located 100 feet below the outfall at the upper end of a pasture. The stream bottom was composed of walnut-sized gravel with islands of aquatic plant communities. In the warmer months, watercress and associated vegetation almost choke the entire stream, and it is in these areas that silt and sludge precipitate around the base of the plant islands. No willows were found in the pasture area.

Station 6 was located 1,000 feet below the outfall at the lower end of the pasture. This area had a substrate of gravel, sand, and small rocks, plus the aquatic plant islands where a few sludge bars and silt collect. Results of the bottom fauna analysis are recorded in Tables 12, 13, and 14 and Figures 198 through 202, Appendix C.

Analysis of bottom fauna (Figures 198-199) from stations 4 and 5 reveals an increase of 36% of the pollution intolerant organisms and an increase of 83% of pollution tolerant kinds (Figure 201). These changes, coupled with a reduction in kinds of organisms (Figure 200), suggested a degrading water situation. Increased pollution tolerant and decreased pollution intolerant populations indicated a continuing degradation between stations 5 and 6. The increase of 0.3 kinds of organisms was not significant in this area to offset the rise of pollution tolerant forms and the reduction in populations of clean water organisms.

The quality of Snake Creek as an aquatic environment was reduced by the impact of the effluent from the Midway Hatchery.

Water Flows

Snake Creek flows are 2.5 times greater than the combined Midway Hatchery outfalls. A dilution of this magnitude would be comparable to that found at Kamas Hatchery. The amount of degradation, however, was not similar at the two hatcheries. The quality of the receiving water at Midway is much lower than at Kamas, allowing a continuance of the degradation process downstream from stations 5 and 6.

Conclusions

Analysis of the waters of Midway Hatchery revealed that the average M.P.N. coliform counts and B.O.D. through the hatchery were increased. Snake Creek, the receiving water, had high levels of B.O.D. before the hatchery effluent was added. M.P.N. coliform counts were also high before the hatchery effluent entered the receiving water. After the effluent entered Snake Creek the concentrations were increased even further.

Concentrations of ammonia found in the Midway Hatchery outfalls and receiving waters were above values that Brockway (1950) reports reduces concentrations of oxygen in fish blood. In an aquatic habitat pH directly affects the toxicity of ammonia. The high carbon dioxide concentration in Midway Hatchery waters and the resultant acidic water apparently reduced the toxicity of ammonia (Tabata, 1962).

The highly buffered water of the Midway Hatchery reduced pH fluctuations. When ammonia was introduced into the hatchery waters this buffering effect allowed high concentrations to persist without producing visible detrimental effects on fish and aquatic organisms.

Suspended solids, turbidity, nitrite, ammonia, B.O.D., and M.P.N. coliform bacteria increased through the hatchery indicating an enrichment of the water. The slight reduction or constant levels of M.O. alkalinity, hardness, settleable solids, specific conductance, TDS, nitrates, D.O., pH and carbon dioxide suggest a stable or increase of water quality.

Analysis of nitrites, nitrates, M.P.N. coliform count, D.O., carbon dioxide and pH show degradation of the receiving water. The results of the other tests on the receiving water indicated a slight increase or stable water quality in Snake Creek. Statistical analysis confirmed the significant increase of nitrite, settleable solids, specific conductance and turbidity in the receiving waters. When these results were weighed and their relative importance and contribution to water quality was considered, the consequences of fish culture on Midway waters resulted in water quality deterioration.

Bottom fauna analysis confirmed the lowering of water quality in Snake Creek. This poorer quality water enabled pollution tolerant organisms to reproduce at a greater rate than those which are intolerant of organic pollution. A decrease in the kinds of organisms also suggests degradation of the receiving water.

Figure 202 shows the relationship of food fed and fish present at the Midway Hatchery. Comparison of this data with chemical analysis revealed little or no correlation between the amount of fish food utilized and/or the pounds of fish in the hatchery system and the water quality of the hatchery effluent.

Even with the degradation of the water quality below the hatchery many nutrients promoted vegetation and bottom fauna growth which is beneficial to the fishery below the hatchery. However, from a public health standpoint the increased M.P.N. coliform and B.O.D. would be detrimental.

LOA HATCHERY

Four stations were chosen to sample Loa Hatchery (Plate 3). The source was the total flow from several springs located along the mountainside. Water was collected in a gravel-filled ditch and fed to a headbox, station 1. Station 2 was the outfall from the hatchery. Stations 3 and 4 were located 100 and 1,000 feet below the outfall, respectively. The situation at this hatchery is unique. The source of Spring Creek, the receiving water, is the hatchery outfall.

Physical-cnemical data is contained in Figures 65 through 80, Appendix A. Statistical analysis is recorded in Table 4, Appendix B. Bottom fauna results are found in Appendix C, Tables 15, 16, and 17 and Figures 203 through 207.

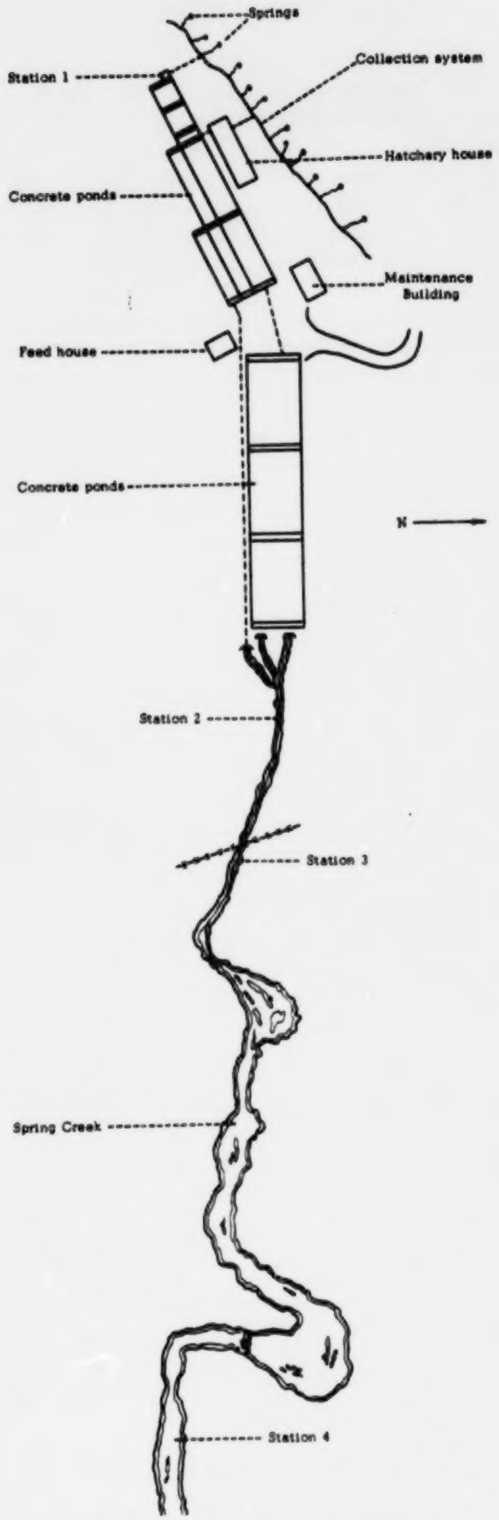
Springs
Station 1
Collection system
Hatchery house
Concrete ponds
Maintenance Building
Feed house
Concrete ponds
N
Station 2
Station 3
Spring Creek
Station 4

Plate 3. Loa Hatchery and Spring Creek showing sampling stations.

Discussion - Physical-Chemical and Bottom Fauna Results

Methyl Orange Alkalinity

M.O. alkalinity concentrations (Figure 65) showed a minimal rise averaging 106 mg/l at station 1 to 110 mg/l at station 4. Spring runoff fluctuations were not apparent in this hatchery system. Hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

Total Hardness

Hardness (Figure 66) did not change appreciably from station 1 (104 mg/l) through station 4 (111 mg/l). The hardness concentrations were not affected by annual runoff and hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population.

Turbidity, Settleable and Suspended Solids

Turbidity, settleable solids and suspended solids (Figures 67, 68 and 69 respectively) were increased through the hatchery. Settleable solid levels averaging less than 0.1 ml/l were recorded for all stations. Suspended solids at station 1 (0.09 mg/l) increased to a high of 5.8 mg/l at station 4. At the same time, turbidity increased from 1.0 Jackson Turbidity Unit at station 1 to 3.4 JTU at station 4. Suspended solids and turbidity reached their highest values at station 4, believed to be the result of direct access of cattle to the stream in the pasture below the hatchery. The changes in turbidity were not significant at the 95% confidence interval while hatchery activities, based on the 95% confidence interval for settleable solids and the 99% confidence interval for suspended solids, significantly altered water quality (Table 1).

Total Dissolved Solids

Total dissolved solids (Figure 70) did not change significantly from station 1 (190 mg/l) to station 4 (200 mg/l) because of hatchery activities. Through the months of January to October, the values were lower then during November and December. There was no apparent reduction during spring runoff. Hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

Specific Conductance

Specific conductance (Figure 71) at station 1 remained constant throughout the year averaging 261 u mhos/cm. The increase of ionizable material added by hatchery activities, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of discharge were from the same population (Table 1).

Nitrates, Nitrites, and Ammonia

Nitrate concentrations (Figure 72) were the same at stations 1, 2, and 3 (averaging 1.67 mg/l). At station 4, possibly because of cattle excrement, the nitrate concentration was approximately 1 mg/l higher. Nitrites (Figure 73) increased 3 fold through the hatchery but remained at the same concentration at stations 2 and 3. At Station 4 nitrite concentrations were increased 40%, believed to be caused by livestock use. Ammonia (figure 74) averaged 0.27 mg/l at station 1 and 0.44 mg/l at station 2. Ammonia concentration decreased at station 3 (0.38 mg/l). The increase of ammonia at station 4 (0.81 mg/l) was again attributed to livestock use. Changes in nitrate concentrations were not significant at the 95% confidence interval while hatchery activity, based upon the 99% confidence interval for ammonia and nitrite, significantly altered water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population on nitrate analysis and from different populations on ammonia and nitrite analysis (Table 1).

MPN Coliform

MPN coliform counts were increased over 9 fold through the hatchery, comparison of stations 1 and 2 (Figure 75). Concentrations at stations 2 and 3 averaged 24,150 bacteria/100 ml, MPN coliform at station 4 averaged 69,900 bacteria/100 ml. This increase could have resulted from the deposition of cattle excrement in and along the stream. Changes in bacteria numbers between stations 1 and 4 due to hatchery activity, based upon the 99% confidence interval significantly altered water quality. Thus, the receiving waters above and below the hatchery discharge were from different populations (Table 1).

Biochemical Oxygen Demand

Biochemical oxygen demand (Figure 76) of water in the hatchery system increased an average of 20 times as it passed through the hatchery. Continued breakdown of food pellets and other organic compounds further increased B.O.D. at station 3 below the outfall to an average of 4.6 mg/l. This increase continued downstream and at station 4 averaged 5.5 mg/l. Hatchery activity, based upon the 99% confidence interval, significantly altered water quality. Thus, the receiving waters above and below the point of hatchery discharge were from different populations (Table 1).

Dissolved Oxygen

Dissolved oxygen (Figure 77) concentrations were reduced by fish usage in the Loa Hatchery. The lower concentrations at station 2 (6.2 mg/l) were increased at station 4 to 6.8 mg/l by riffles, waterfalls and plant action in the stream below the hatchery. Hatchery activity, based upon the 99% confidence interval, significantly altered water quality. Thus, the receiving waters above and below the point of hatchery discharge were from different populations.

Carbon Dioxide and Hydrogen Ion Concentration

Carbon dioxide (Figure 78) is raised 400% above an average of 0.14 mg/l at station 1 by hatchery activity. This increase lowered hydrogen ion concentrations (Figure 79) at station 2 an average of about 0.2 of a pH unit. Loss of carbon dioxide at station 3 resulted from agitation over riffles between stations 2 and 3. Station 4 carbon dioxide concentrations averaged 0.5 mg/l, but pH values did not decrease. Hatchery activity, based upon the 99% confidence interval, significantly altered water quality. Thus, the receiving waters above and below the point of hatchery discharge were from different populations (Table 1).

Temperature

The effect of the hatchery on temperatures is negligible (Figure 80). The spring remained a nearly constant 60 degrees F. throughout the year and the lower stations fluctuated with the seasons. Temperature in these areas ranged from a minimum of 56 degrees F., to a maximum of 64 degrees F. Hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the hatchery discharge were from the same population (Table 1).

Bottom Fauna

Bottom fauna organisms were gathered with the Surber-square foot sampler at stations 1, 2, and 4 (see Plate 3 for layout). The invertebrates at station 1 lived in a substrate of walnut-sized gravel, interspersed with watercress and other small aquatic plants. Springs flowed from the ground in many small rivulets which were collected into a head box, station 1. Representative samples were selected from these small streams above the collection canal.

In station 2, below the hatchery, there were softball-sized rocks mingled with smaller gravel and sand. Watercress grew abundantly through the summer months along the shore. The lower sampling area, station 4, was characterized with a sand and gravel bottom with a moderate number of larger rocks stabilizing the substrate. Little vegetation occurs on the banks in this area except grasses and sedges, and these are cropped close by grazing cattle.

The concentrations and variety of invertebrates (Figures 203 and 204) which occurred at these sampling sites was indicative of the enrichment added by the hatchery. This enrichment resulted in a 6.8% (Figure 206) increase in number of pollution intolerant organisms and a 68% increase in pollution tolerant invertebrates. In some of the slower reaches, solids were precipitated and small silt and sludge beds were found. These areas were also sampled along with the more open sectors providing a better representative sample of all organisms present in the stream.

The creek running below station 2 to station 4 permitted some recovery with a resultant 64% increase of clean water organisms and a 40% decrease of pollution tolerant invertebrates. This large increase of clean water organisms (Figure 204) occurred at station 4 notwithstanding the presence of additional nutrients contributed to the stream by cattle pastured in this area.

The change in kinds of organisms (Figure 205) throughout the study area was found to be minimal, indicating that the eutrophication of the stream by the Loa Hatchery, though present, did not alter the composition of aquatic invertebrates to any great extent.

Flows

The spring flow at the Loa Hatchery forms the major portion of Spring Creek below the hatchery. The median flow was 18 CFS which carried the total chemical and biological loadings from the hatchery. Water flows from this source did not vary as widely as in sources from other hatcheries.

Conclusions

Chemical analysis of the Loa Hatchery water revealed that B.O.D., M.P.N. coliform bacteria, suspended solids, ammonia and carbon dioxide were increased by hatchery activities.

M.O. alkalinity, total hardness, specific conductance, total dissolved solids, nitrates, and temperatures did not change significantly because of hatchery activities.

Analysis of variance were conducted on the changes made by the hatchery on the stream. Nitrite, settleable solids, ammonia, B.O.D., MPN coliform, suspended solids, dissolved oxygen, pH and carbon dioxide were changed significantly. These changes confirmed an enrichment of the water where many more organisms were present to utilize the available nutrients.

Bottom fauna analysis showed that the influence of the Loa Hatchery is one of enrichment. The high quality water which the hatchery used permitted greater concentrations of detrimental chemicals to be placed into the water before any degradation was observed. Increased growth and greater numbers of bottom fauna organisms indicated a beneficial result from the hatchery activities.

Consideration of the above factors reveal that the hatchery degraded the quality of the water. Comparison of the three lower stations shows a continuing degradation of water quality in Spring Creek. The hatchery influence was shown in the difference in water quality at stations 1 and 2. Further degradation of the stream is a result of some other factor, such as livestock use in the stream below the hatchery.

As in Kamas and Midway hatcheries, the expected increased pollutional loadings do not correspond with the increased use of food for a larger number of fish in the hatchery (Figure 207).

WHITE TROUT FARM

Water courses sampled at White's Trout Farm consisted of four inflows (stations 1 through 4) and two outfalls at stations 6 and 7. A third outfall used for irrigation purposes did not enter Little Bear River and was not sampled. See Plate 4 for layout. Station 1, source water from Little Bear River, was used in the ponds and runs. The springs at stations 2, 3, and 4 were used for growing fry and fingerling. For facility in analysis, the data for these three springs was combined into one station, designated as station 2. Chemical characteristics of these springs did not vary sufficiently to warrant separation. The two outfalls, stations 6 and 7, were located at the lower end of the hatchery complex and entered the Little Bear River about 100 feet apart.

The impact that hatchery effluent had on the Little Bear River was assessed by comparing station 5, found above the outfalls, with stations 8 and 9 which lie downstream from the outfall 100 feet and 1,000 feet, respectively.

Physical and chemical data can be found in Appendix A, Figures 81 through 112 and statistical analysis is recorded in Table 5, Appendix B. Bottom fauna analysis is tabulated in Appendix C, Tables 18, 19 and 20 and Figures 208 through 212.

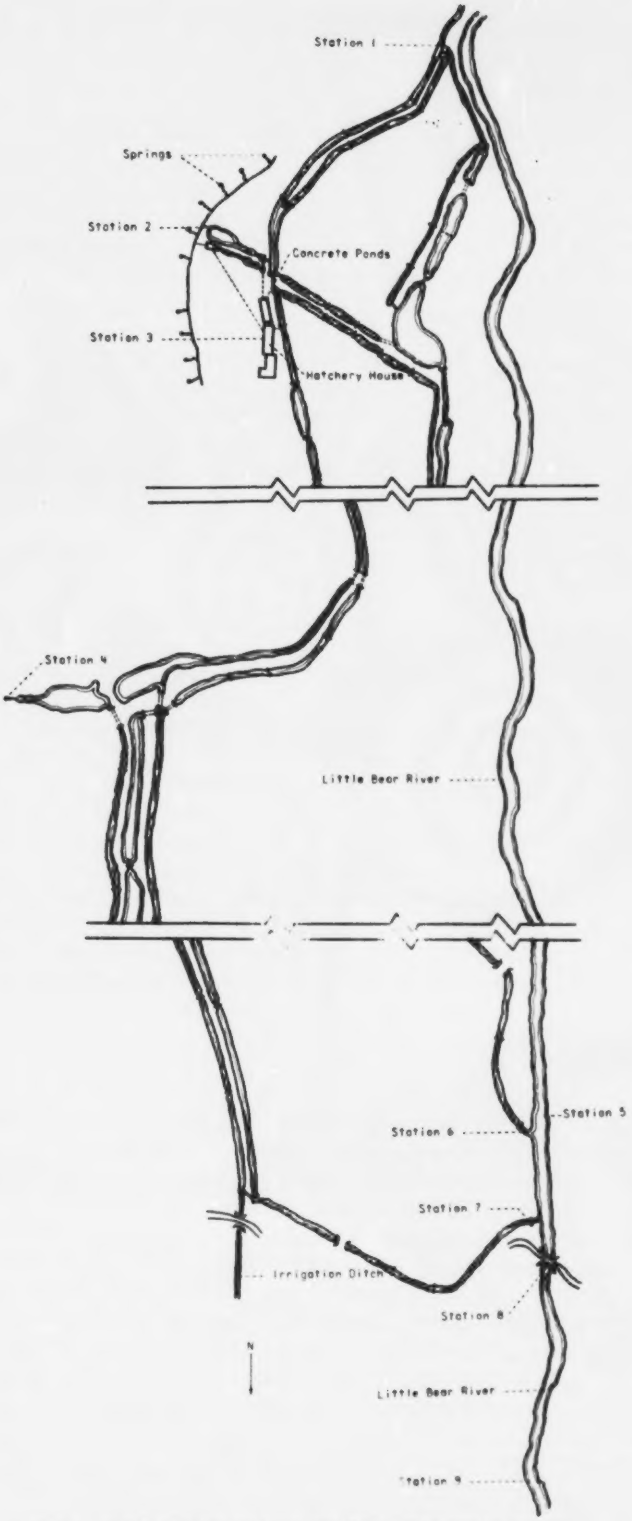
Station 1
Springs
Station 2
Concrete Ponds
Station 3
Hatchery House
Station 4
Little Bear River
Station 5
Station 6
Station 7
Irrigation Ditch
Station 8
N
Little Bear River
Station 9

Plate 4. White's Trout Farm and Little Bear River showing sampling stations.

Discussion - Physical-Chemical and Bottom Fauna Results

Methyl Orange Alkalinity

Figures 81 and 82 for M.O. alkalinity show concentrations at the various stations. Concentrations at station 2, the springs, averaged 36 mg/l higher than Little Bear River water. The levels of M.O. alkalinity at station 2 remained constant throughout the year, while Little Bear River water (station 1) varied between 100 mg/l and 260 mg/l. The outfalls, stations 6 and 7, reflected the lower values of station 1 rather than the spring water.

There was no great difference in concentrations of M.O. alkalinity between the clean water station (5) and the lower receiving water stations (8 and 9). A reduction of values during the spring runoff in April and May was evident. The decrease on the second sample in January reflected dilution brought about by a severe rainstorm. Hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

Total Hardness

Total hardness followed the same pattern as the M.O. alkalinity and averaged highest at station 2 (277 mg/l), Figure 83. Hardness was reduced by high runoff periods during January and again in April and May. The outfalls, stations 6 and 7, reflected concentrations found at station 1, averaging 235 mg/l hardness.

The receiving water (Figure 84) above the outfall at station 5, had an average increase of 12 mg/l above station 1 which was the source of this water. The lower receiving water stations were reduced an average total hardness about 1%. Hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

Turbidity

Turbidity (Figures 85 and 86) increased slightly through the hatchery. Very little turbidity is contributed by the springs (station 2). The highest concentrations (24.8 JTU) enter the hatchery at station 1, a diversion of Little Bear River. Outfalls at stations 6 and 7 averaged only 1.2 JTU below this influent water. The addition of hatchery effluent increased receiving water concentrations from 26.5 JTU at station 5, to 28.6 JTU at station 8. Turbidity at station 9 increased after complete mixing had occurred. Hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1). A severe rainstorm and flood in January and the spring runoff in April and May caused turbidity to increase throughout the system.

Settleable Solids

Hatchery operations increased settleable solids (Figures 87 and 88) about 3 fold. The springs, station 2, contributed minute quantities of settleables while the incoming Little Bear River water contributed an average of 0.1 ml/l. Outfall stations 6 and 7 averaged 0.29 ml/l. Higher concentrations were noted during June at station 6 and in September at station 7. Although large amounts of settleable solids were released at station 6, they settled before there was an observable influence on station 8. When station 7 carried high concentrations of settleable solids, a direct effect was caused on station 8. Station 9 averaged 0.32 ml/l settleable solids throughout the year. Hatchery activity, based upon the 95% confidence interval between stations 5 and 9, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

Suspended Solids

Concentrations of suspended solids at the springs and influent from the Little Bear River averaged 2.1 mg/l and 27.7 mg/l, respectively. They were increased 20% through hatchery activities (Figures 89 and 90). Values at station 5 averaged 26.9 mg/l and were increased at station 8 to 48.4 mg/l by the addition of hatchery effluent. At station 9 suspended solids were increased to concentrations higher than at station 5. Hatchery activity, based upon the 95% confidence interval did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

Total Dissolved Solids

Hatchery activities increased total dissolved solid (Figures 91 and 92) concentrations 14% over the influent source at station 1 which averaged 285 mg/l. The effluent when added to station 5 (317 mg/l) raised the values in the receiving water 9%. After thorough mixing at station 9 the concentrations were not increased above those levels found at station 5. Hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

Specific Conductance

Specific conductance is an index of concentrations of ionizable material in water. The average values of specific conductance of the influent waters (Figure 93) at stations 1 and 2, were 505 u mhos/cm. These readings are reduced approximately 12% through hatchery activities. When this effluent was added to the Little Bear River, the average specific conductance of station 5 (527 u mhos/cm) was decreased 8% (Figure 94) below the concentrations at stations 8 and 9. Hatchery activity, based upon the 95% confidence interval did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were the same population (Table 1).

Nitrate

Average nitrate concentrations (Figures 95 and 96) in the springs (station 2) were 3 times that found at station 1 (1.91 mg/l) on the Little Bear River. The levels through the hatchery were increased 21% over the source waters. Concentrations in the outfalls averaged 2.43 mg/l and increased the levels in the receiving waters about 36% above the 1.6 mg/l nitrate found at station 5. Hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

Summer and early fall levels were higher than those found the remainder of the year.

Nitrite

Nitrite (Figures 97 and 98) is a product of bacterial degradation on ammonia and other organic compounds and was more than trippled between the source and hatchery outfalls. The source water recorded average levels of 0.008 mg/l and the outfalls a level of 0.028 mg/l nitrite. The effect of the concentrations of nitrites introduced by the hatchery was seen in the 5% increase of this product in the receiving water at station 8 over station 5. Nitrite levels were lower in station 9 than in station 8. However, hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the point of hatchery discharge were from the same population (Table 1).

Ammonia

Ammonia concentrations (Figure 99) at stations 1 and 2 averaged 0.25 mg/l. These values were 59% greater in the outfalls by the addition of fish excretory products and breakdown of organic nitrogen compounds. Some concentrations measured at White's Trout Farm were above those which are known to affect fish metabolism (Brockway, 1950). When these concentrations from stations 6 and 7, were combined with those found at station 5 (0.37 mg/l) on the receiving water (Figure 100), the resultant levels were raised 46% at station 8. Ammonia levels at station 9 were somewhat higher than the above station. Ammonia concentration changes between stations 5 and 9 due to hatchery activity, based upon the 99% confidence interval, significantly altered water quality. Thus, the receiving waters above and below the point of hatchery discharge were from different populations (Table 1).

MPN Coliform

MPN coliform bacteria counts (Figure 101) were increased 44 times through the hatchery over the average concentration in the source waters of 3,000 bacteria/100 ml. Little Bear River counts at station 5 (Figure 102) averaged over 65,000 coliform bacteria per 100 ml of water. This concentration was increased over three-fold after the hatchery outfall was added, station 8. Concentrations at station 9 were 4.8 times higher than those found at station 5. Hatchery activity, based upon the 99% confidence interval, significantly altered water quality. Thus, the receiving waters above and below the point of hatchery discharge were from different populations (Table 1).

Biochemical Oxygen Demand

Biochemical oxygen demand (B.O.D.) concentrations (Figure 103) averaged 1.0 mg/l for the source waters. Adding food and waste products to the hatchery water increased B.O.D. 6.5 times. The hatchery effluent, when combined with station 5 (Figure 109), which had an average concentration of 3.7 mg/l B.O.D., increased B.O.D. levels at station 8 over 200%. B.O.D. concentrations continued to increase downstream an additional 8%, between stations 8 and 9. Stations 1 and 5 are from the Little Bear River source, but station 5 B.O.D. levels are over 3 times higher, possibly because of livestock use between these stations. Increases of B.O.D. as a result of hatchery activity based upon the 99% confidence interval, altered water quality. Thus, the receiving waters above and below the point of hatchery discharge were from different populations (Table 1).

Dissolved Oxygen

Fish utilization reduced dissolved oxygen (D.O.) levels slightly through the hatchery (Figure 105). The addition of the hatchery effluent to Little Bear River also reduced D.O. levels at stations 8 and 9 (Figure 106). However, the concentrations encountered were not decreased to levels which would be critical for fish propagation. The reduction between stations 5 and 9 due to hatchery activity, based upon the 99% confidence interval, significantly altered water quality. Thus, the receiving waters above and below the point of hatchery discharge were from different populations (Table 1).

Carbon Dioxide and Hydrogen Ion Concentrations

Carbon dioxide values (Figure 107) were found to be highest in the spring sources. Hydrogen ion concentrations (Figure 109) were consequently lower. Incoming water from Little Bear River had lower carbon dioxide and higher pH averaging differences of 0.6 mg/l and 0.7 pH unit, respectively, than the springs, station 2. Carbon dioxide concentrations were lowered through the hatchery, accompanied by no apparent change in pH. An average reduction of 0.5 mg/l of carbon dioxide through the hatchery could be attributed to aeration and photosynthetic action in the dirt ponds. The hatchery effluent increased the average carbon dioxide concentrations between stations 5 and 8 (Figure 108) with an average decrease of pH of 0.6 of a unit. Aeration in Little Bear River between stations 8 and 9 permitted additional carbon dioxide to escape into the atmosphere resulting in a rise of pH at station 9. The decrease of carbon dioxide from station 5 to station 9 due to hatchery activities, based on the 99% confidence interval, significantly altered water quality while at the same time pH changes did not significantly alter water quality at the 95% confidence interval (Table 1).

Temperature

Water temperatures (Figure 111) at the hatchery springs varied only 3.5 degrees F. throughout the year. Little Bear River water, stations 1 and 5, the outfalls station 6 and 7, and the lower receiving water, stations 8 and 9, varied from a low of 33.5 degrees F., in the winter to a high of 66.0 degrees F. in the summer.

Bottom Fauna

Bottom fauna was collected and later analyzed from stations 5, 8 and 9 on the receiving water of White's Trout Farm (see Plate 4 for layout). Station 5 was designated as the clean water area. It included interspersed rubble and football-sized boulders. These rocks were normally covered uniformally with short filamentous algae growth throughout most of the year. The banks were lined with high willows shading part of the stream.

The same substrate was found 100 feet below the outfalls at station 8, but the filamentous algae had been partially replaced with sewage fungus (*Sphaerotilus natans*). This growth flourishes in water enriched with organic material. The hatchery effluent from station 7 had not mixed completely with Little Bear River so only a portion of the stream was covered with the growth of sewage fungus.

Station 9 was located 1,000 feet downstream and was composed of stable rubble, gravel and sand. Filamentous algae predominated with a few patches of sewage fungus adhering to the rocks during low flow periods in late summer. High willows and Box Elder trees lined the banks in this section of the river. Results of the bottom fauna analysis are contained in Tables 18, 19 and 20 and Figures 208 through 212 (Appendix C). Relative numbers of pollution and clean water organisms collected at stations 5, 8 and 9 are summarized in Figures 208. Throughout all the sections, the numbers of pollution tolerant organisms exceeded those of the clean water forms (Figure 209).

At station 5 pollution tolerant organisms (Figures 208 and 209) were about three times as abundant as the clean water forms, but after the hatchery effluent was added at station 8 the abundance of pollution tolerant organisms exceeded clean water forms by a ratio of 25 to 1. The large increase of pollution tolerant organisms and the subsequent loss of seven kinds of organisms (Figure 210) was indicative of a biologically degraded water environment immediately below the outfalls.

At station 9 the river began to recover. Numbers of pollution tolerant organisms were reduced 10 percent (Figure 211) below those at station 8, and clean water organisms recovered 58 percent, but the numbers of kinds of organisms had not returned in abundance to those concentrations found above the hatchery outfalls at station 5.

Water Flows

Flows (cfs) were measured monthly throughout the sampling year and were highly variable. Because of the variability, some of which was contributed by measurement error, the median of the range of flow from the outfalls and receiving water was compared. The outfalls contributed 1/2 at the minimum flow to 1/3 at maximum flows of the Little Bear River. A greater pollutional effect on the receiving water was evident in low late-fall flows than during high water flows in the spring.

Conclusions

Changes in chemical and bottom fauna quality of the water as a result of White's Trout Farm activities is discussed in two phases. First, the effects on the water flowing through the hatchery and second, the effects on the receiving water.

Settleable and suspended solids, turbidity, total dissolved solids, nitrites, ammonia, B.O.D., M.P.N. coliform, and carbon dioxide increased, while D.O. and pH were reduced. This degradation of water quality progressed through the hatchery. Other tests, which had little or no reduction in concentrations, were M.O. alkalinity, total hardness, specific conductance, and nitrates. Of this group, nitrates have the greatest significance in assessing the degree of pollution on a body of water. Nitrates were possibly assimilated by aquatic vegetation before large concentrations were built up.

The chemistry of the receiving water was changed when the outfalls were added. Settleable and suspended solids, turbidity, TDS, nitrates, ammonia, B.O.D., M.P.N. coliform, and carbon dioxide were increased indicating a degradation of water quality in Little Bear River. Statistical analysis of the various parameters showed a significant change in concentrations of ammonia, B.O.D., M.P.N. coliform, dissolved oxygen and carbon dioxide. These changes are indicative that the hatchery activities were degrading the waters of the Little Bear River.

Analysis of bottom fauna collections revealed a large increase of pollution tolerant organisms accompanied by a reduction in pollution intolerant forms between stations 5 and 8. Numbers of kinds were reduced drastically between these two stations also denoting a degradation of the aquatic habitat. An increase in numbers and kinds of organisms found at station 9, 1,000 feet below the outfall, suggested a recovery from the degradation evidenced at station 8.

Chemical parameters and bottom fauna examined for hatchery and receiving waters indicated deterioration of water quality.

The amounts of wet food and dry food pellets used at White's Trout Farm are shown in Figure 212. Information for the poundage of fish fed each food was not available. Of all parameters mentioned only the nitrate and nitrite levels could be correlated with feeding levels which were highest from June through October. The significance of this correlation is somewhat diminished because of the lack of correlation of the B.O.D., ammonia, and M.P.N. coliform tests with the amount of food fed. Based on results from this study, the amount of food fed had little or no relationship with the eutrophication of the outfall waters. The level of enrichment was related to fish metabolism and its waste materials. These results, therefore, are similar to those found for the previous hatcheries.

SPRINGVILLE - STATE AND FEDERAL HATCHERIES

The Federal and State hatcheries at Springville, Utah, formed a complex of inflows and outfalls that influenced each other in chemistry and bottom fauna characteristics. Layout of the two hatcheries can be seen in Plate 5. Station 1 was the source for the Federal hatchery and a partial source for the State hatchery. Station 2 was a spring used at the State hatchery for supplying the hatchery house. Station 3 was the total outfall of the State hatchery. Outfalls for the Federal hatchery included stations 5, 10, 11 and 12, the latter was the outfall of a pond. Stations 8 and 9 were outfalls of growing ponds but were not sampled for this study because the ponds were not used during the sampling period. Station 4, 100 feet below State outfall, was divided into two streams, one was diverted through the inoperative Geneva Steel-Ironton Works (Ironton Canal) and the other flowed into Utah Lake. Comparison of station 4 with stations 6 and 7 showed the influence of the outfall from the Federal hatchery, station 5, on this water. Comparison of station 4 with stations 13 and 14 indicated changes due to the other Federal outfalls, stations 10, 11 and 12. Comparing stations 6 and 12 revealed changes through the fingerling pond.

Physical and chemical results are collected in Appendix A, Figures 113 to 192 inclusive. Statistical analysis of the receiving waters is recorded in Tables 6, 7 and 8, Appendix B. Summaries of bottom fauna collections are listed in Appendix C, Tables 21 through 24 and Figures 213 through 218.

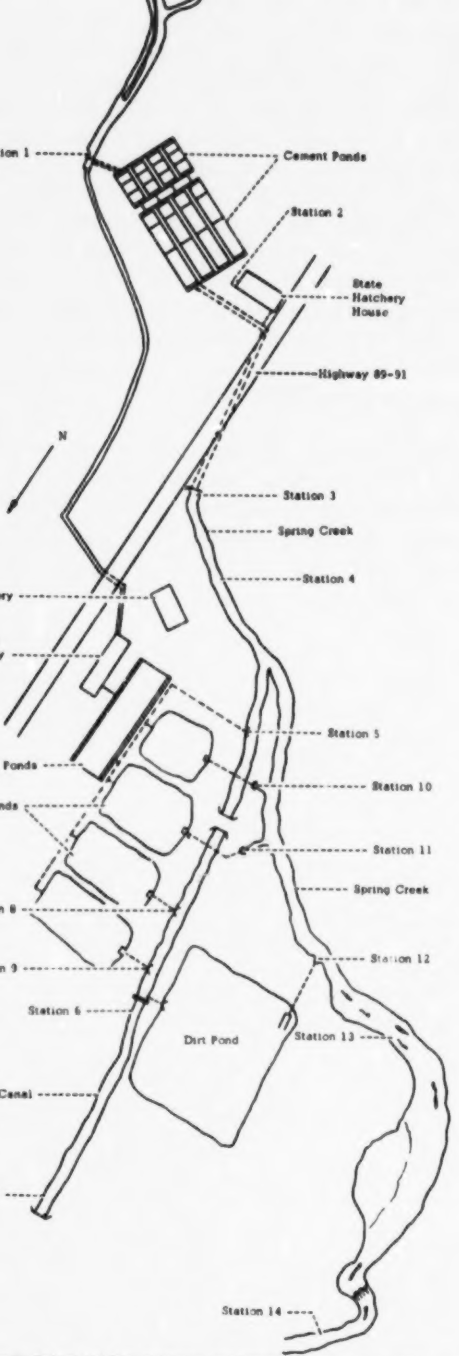
Springs
Station 1
Cement Ponds
Station 2
State Hatchery House
Highway 89-91
N
Station 3
Spring Creek
Station 4
Laboratory
Federal Hatchery House
Station 5
Cement Ponds
Station 10
Dirt Ponds
Station 11
Spring Creek
Station 8
Station 12
Station 9
Station 6
Dirt Pond
Station 13
Ironton Canal
Station 7
Station 14

Plate 5. Springville Federal and State Hatcheries and Spring Creek showing sampling stations.

Discussion - Physical-Chemical and Bottom Fauna Results

Methyl Orange Alkalinity

Methyl orange alkalinity (Figures 113 through 117) was stable at all stations throughout the year. Average M.O. alkalinity increased 5% through the Federal hatchery. All other stations examined averaged 235 mg/l alkalinity throughout the year with no apparent annual runoff dilution. The changes of M.O. alkalinity in the receiving water due to State and Federal hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the hatchery discharges were from the same population (Table 1).

Total Hardness

Hardness (Figures 118 through 122) was found to fluctuate considerably throughout the year with minimum readings at all stations the first collection in June. Station 2 averaged 40 mg/l lower than other hatchery stations. Average concentrations at station 11, one of the outfalls from the Federal Hatchery, had concentrations 35 mg/l above the inflow, station 1. Other stations in the hatchery complex were within 10 mg/l of the average of 374 mg/l total hardness. The changes of hardness due to State and Federal hatchery activities, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the hatchery discharges were from the same population (Table 1).

Turbidity

Turbidity concentrations (Figures 123 through 127) were increased as the water supply traversed the hatchery and raceway systems. Turbidity of the State hatchery increased 9%, and at the Federal hatchery, 12% above the inflow concentration of 1.26 Jackson Turbidity Units, station 1. Turbidity in the receiving waters, Spring Creek and the Ironton Canal, were reduced by slow flows and filtration in a watercress-choked waterway. Concentrations were generally lowered during the months of March, April, and May. State hatchery activity, based upon the 95% confidence interval, did not significantly alter water quality while federal hatchery activities, based upon the 95% confidence interval significantly altered water quality in the Ironton Canal and based upon the 99% confidence interval, significantly altered water quality in Spring Creek (Table 1).

Settleable Solids

Settleable solids (Figures 128 through 132) showed an increase in concentrations throughout both hatcheries and raceway systems. The levels of this parameter were very low, averaging less than 0.2 ml/l so that the changes were minimal. Settleable solids were reduced in the Ironton Canal because the stream was deep with low velocity which allowed many particles to precipitate. An increase in settleable solids in Spring Creek was apparently caused by the activity of cattle which had direct access to the stream. Spring runoff did not noticeably affect the amount of settleable solids in the receiving waters. The changes in settleable solids due to hatchery activities, based upon the 99% confidence interval, significantly altered water quality in Spring Creek only. Thus, the receiving waters above and below the Federal hatchery discharges on Spring Creek are from different populations (Table 1).

Suspended Solids

Concentrations of suspended solids (Figures 133 through 137) at the source spring, station 1, averaged 0.48 mg/l and increased about 5 fold after traversing the State hatchery and increased 12 fold through the Federal hatchery. Suspended solids were an average of 1.33 mg/l higher at the outfall of the Federal fingerling pond. Values at station 4 averaged 3.18 mg/l which increased at stations 6 and 13 by the addition of hatchery effluent. At stations 7 and 14 suspended solids were even higher than at stations 6 and 13 respectively. Spring runoff did not influence the levels of suspended solids. State and Federal hatchery activities, based upon the 99% confidence interval, significantly altered water quality in all receiving waters. Thus, the receiving waters above and below the point of hatchery discharges were from different populations (Table 1).

Total Dissolved Solids

Total dissolved solids concentrations (Figures 138 through 142) increased about 3% at the State hatchery, 6% at the Federal Hatchery and 1% at the fingerling pond. After the effluent was added to the receiving water at station 4 which had an average concentration of 656 mg/l the values increased 2% in the Ironton Canal and 4% in the lower Spring Creek. The lowest concentration of T.D.S. was noted in January with the high point in the late September sample. Shortly before the September collection, the hatcheries had been disinfected to eliminate infectious pancreatic necrosis virus. Federal hatchery activities, based upon the 95% confidence interval, significantly altered water quality in Spring Creek while the State and Federal hatchery (Ironton Canal) receiving waters were not altered significantly at this same confidence interval.

Specific Conductance

Specific conductance measures concentrations of ionizable material in water and are recorded in Figures 143 through 147. The State hatchery concentrations were increased an average of 3% although station 2 averaged 90 u mhos/cm less than station 1. Federal hatchery outfalls averaged 965 u mhos/cm, the same as the influent water of station 1. The use of the water through the fingerling pond increased specific conductance 14 u mhos/cm. The Ironton Canal water averaged 990 u mhos/cm for stations 4, 6 and 7. Spring Creek conductance increased an average of 15 u mhos/cm, as a result of hatchery effluent contribution. State hatchery activity, based upon the 99% confidence interval, significantly altered water quality while Federal hatchery activities did not significantly alter water quality at the 95% confidence interval (Table 1).

Nitrate

Nitrate concentrations are depicted in Figures 148 through 152. Hatchery use decreased nitrates in the water. Station 2, the hatchery house spring, was 33% higher than station 1(2.49 mg/l), but its contribution to the total flow was so small that there was little change in the outfall concentrations. The water through the Federal Hatchery and fingerling ponds was reduced 10% and 3%, respectively. The concentrations found at the Federal hatchery decreased the levels in the Ironton Canal 4.8% and Spring Creek 11% below the 2.6 mg/l found at station 4. Hatchery activities, based upon the 95% confidence interval, did not significantly alter water quality. Thus, the receiving waters above and below the hatchery discharges were from the same population (Table 1).

Nitrite

Nitrite (Figures 153 through 157) is a product of bacterial degradation on ammonia and organic substances. The source waters averaged 0.01 mg/l. The State hatchery increased these concentrations 2.5 times and the Federal hatchery increased nitrite levels almost 3 fold. Nitrite concentrations were doubled as the water supply traversed the Federal fingerling pond. The effect of nitrite concentrations in the effluent from the Federal hatchery resulted in an almost 3 fold increase of this product in Spring Creek, station 13. Bacterial degradation of ammonia and organic nitrogen products continued downstream, and was reflected in nitrite levels which were almost doubled between stations 13 and 14. Nitrites readily oxidize to nitrates, and some correlation would be expected between these two anions. However, in this case, there were no discernible relationships to indicate this was true. No increase was noted in the Ironton Canal between stations 6 and 7. State hatchery activity, based upon the 95% confidence interval, significantly altered water quality in upper Spring Creek. Federal hatchery activities, based upon the 99% confidence interval, significantly altered water quality in lower Spring Creek but in the Federal receiving water (Ironton Canal) the change in nitrite concentrations were not significant at the 95% confidence interval (Table 1).

Ammonia

Ammonia concentrations (Figures 158 through 162) at station 1 averaged 0.24 mg/l. These were 33% higher at the State hatchery outfall and averaged 37% higher at the Federal hatchery outfalls. The ammonia content of the water supply was reduced 23% while traversing the Federal hatchery fingerling pond. When these concentrations were combined with the receiving water below station 4 (0.38 mg/l), the resultant ammonia levels increased 28% at station 6 and 47% at station 13. Unaccountably, ammonia levels at stations 7 and 14, were higher than at stations 6 and 13 respectively. State and Federal hatchery activities, based upon the 99% confidence interval, significantly altered water quality in the receiving waters. Thus, the receiving waters above and below the hatchery discharges were from different populations (Table 1).

M.P.N. Coliform

M.P.N. coliform bacteria counts (Figures 163 through 167) were increased 28 fold by effluent from the State hatchery and 93 fold by effluents from the Federal hatchery, based on average concentrations in the source water (Station 1) of 742 bacteria/100 ml. Coliform bacteria concentrations doubled in the Federal fingerling pond. Upper Spring Creek counts (Station 4) averaged 13,660 coliform bacteria/100 ml of water which increased about 2.5 times in the Ironton Canal and almost 100 fold in the lower Spring Creek. Concentrations at station 7 and 14 continued to increase above those found at stations 6 and 13 respectively. State and Federal hatchery activities, based upon the 99% confidence interval, significantly altered water quality. Thus, the receiving waters above and below the hatchery discharges were from different populations (Table 1).

Biochemical Oxygen Demand

Biochemical oxygen demand (B.O.D.) concentrations (Figures 168 through 172) averaged 0.07 mg/l for the source springs. Adding food and waste products to the water supply at the State hatchery increased B.O.D. 12 fold and at the Federal hatchery raised B.O.D. levels 59 fold. When this effluent was mixed with an average concentration of 3.2 mg/l B.O.D. of Spring Creek at station 4 the levels were increased 17% in the Ironton Canal at station 6. After hatchery effluents were added to Spring Creek at station 13, B.O.D. increased 19%. Concentrations continued to increase at station 7 on the Ironton Canal and station 14 on Spring Creek. State and Federal hatchery activities, based upon the 99% confidence interval, significantly altered water quality. Thus, the receiving waters above and below the hatchery discharges were from different populations (Table 1).

Dissolved Oxygen

Fish utilization reduced D.O. levels slightly through the hatchery systems (Figures 173 through 177). An average reduction in D.O. of 0.2 mg/l occurred at the State hatchery and at the Federal hatchery the reduction averaged 0.9 mg/l. D.O. levels decreased 0.4 mg/l in the Federal hatchery fingerling pond.

Dissolved oxygen concentrations in the Federal fingerling pond became critical for fish propagation during the period of February through May so special aeration equipment was employed to alleviate the situation. Dissolved oxygen concentrations in Ironton Canal receiving water were not reduced significantly and the D.O. in Spring Creek receiving water was enhanced by photosynthetic action, riffles, and waterfalls. State and Federal hatchery activities, based upon the 95% confidence interval, significantly altered water quality in Upper Spring Creek and Ironton Canal while at this confidence interval lower Spring Creek water quality was not significantly altered.

Carbon Dioxide and Hydrogen Ion Concentration

Carbon dioxide concentrations (Figures 178 through 182) were lowered in the State and Federal hatcheries, while pH remained stable at 7.3 (Figures 183 through 187). Aeration by baffles in the raceways resulted in a reduction of the average carbon dioxide concentration from 6.8 mg/l at the source spring to an average of 4.7 mg/l in the outfall of the State hatchery. Carbon dioxide concentrations in Federal hatchery were reduced from 6.8 mg/l at the springs to 5.0 mg/l at the outfalls. The effects of propagation in the Federal fingerling pond increased carbon dioxide an average of 0.5 mg/l accompanied by no change in pH. The effect of the Federal hatchery effluent on the Ironton Canal decreased carbon dioxide concentrations 1.1 mg/l while the pH remained stable at 7.4.

Average carbon dioxide concentrations in Spring Creek receiving water were reduced from 5.1 mg/l at station 4 to 3.1 mg/l at station 13 to 2.0 mg/l at station 14 by the influence of hatchery effluent. Hydrogen ion concentrations increased from 7.4 at station 4 to 7.6 at station 14 as carbon dioxide was liberated into the atmosphere by aeration over riffles and utilization in photosynthesis. State and Federal hatchery activities, based upon the 99% confidence interval, reduced carbon dioxide levels significantly to alter water quality. Hatchery activities, based upon the 95% confidence interval, did not change pH or water quality significantly. Thus, the receiving waters above and below the hatchery discharges were from different populations with carbon dioxide and were from the same population with pH (Table 1).

Temperature

Water temperatures (Figures 188 through 192) in the State hatchery fluctuated within a range of 11°F., and the Federal hatchery temperatures varied 16°F. The median for both hatcheries was 59°F. A low winter temperature of 44°F. was recorded for Spring Creek and the Federal fingerling pond, and the summer high for these waters was 66°F. The Ironton Canal ranged from a winter low of 53°F. to a summer high of 63°F.

Bottom Fauna

Bottom fauna was collected and later analyzed from stations 1, 4, 7 and 14 on the source and receiving waters of the Springville hatcheries (see Plate 5 for layout). The substrate found at station 1, located above the hatcheries, consisted of walnut-sized gravel. Some aquatic weeds and watercress lined the banks and the bottom gravel was covered with filamentous algae. There was no tree or shrub cover along the banks.

The substrate at station 4, the State hatchery outfall, and also the upper receiving water station for the Federal hatchery, was football-sized boulders interspersed with rubble. During the summer luxuriant growths of watercress grew in the slower flowing reaches and along the banks.

Station 7, located 1,000 feet below station 5 outfall, had a substrate of pea-sized gravel interspersed with areas where silt and sludge had precipitated around the base of the plants to form islands. Willows line the east bank of the Ironton Canal at this sampling station.

Station 14, located 1,000 feet below station 12 on Spring Creek, had a substrate of rubble and small gravel interspersed with islands of small vegetation. Watercress with small concomitant sludge beds were found at station 14. The stream was shaded throughout the day by large cottonwood trees.

Bottom fauna collections are summarized in Tables 21 through 24 and Figures 213 through 218, Appendix C.

At station 1 pollution intolerant organisms outnumbered pollution tolerant organisms about 2.5 to 1 (Figures 213 and 214). This situation is indicative of a relatively clean water situation. Station 4 contained 4.4 pollution tolerant organisms for each of the clean water variety. This was an increase of 96% for pollution tolerant organisms (Figure 216) and 52% for clean water organisms above those found at station 1. State hatchery activities resulted in an increase of 0.6 in kinds of organisms.

Numbers of organisms at station 7 in the Ironton Canal were dramatically reduced by the effects of hatchery effluents. Pollution tolerant organisms were reduced by 87% and clean water invertebrates were reduced by 48% compared to station 4. The numbers of kinds (Figure 215) were reduced to levels found at station 1. A reduction of available habitat was responsible for the reduction in numbers of organisms and kinds of organisms.

Bottom fauna at station 14 approximated the numbers of invertebrates found at station 7. Numbers of kinds of organisms were higher at station 14 than at station 7, which suggested an improved situation in the Spring Creek arm of the receiving water.

Although Spring Creek was degraded as a hygenic water source by State hatchery activities, there was a great increase of pollution tolerant organisms accompanied by a moderate increase of pollution intolerant invertebrates, which was beneficial from a fisheries viewpoint.

The Federal Hatchery also degrades Ironton Canal and Spring Creek but to a lesser degree than the State hatchery. In retrospect, however, it is believed that two additional sampling areas could have been chosen to give a more exact evaluation of the effects of effluent from the Federal hatchery. These stations should have been located below stations 5 and 12.

Water Flows

Station 3 composed the total outfall flow from the State hatchery. This flow ranged from 14 to 18 cfs. Four flows composed the total outfall from the Federal hatchery. Station 5 constituted about 40% of the Federal hatchery flow. The other outfalls, stations 10, 11 and 12 contributed the remainder of the hatchery outfall flow. Measurement error in estimating partial flows was as high as 10% of the total outfall from the Federal hatchery. Impact of the effluent from the Federal hatchery was greater on Spring Creek than on the Ironton Canal.

Conclusions

The complex arrangement of outfalls from the State and Federal hatcheries at Springville caused difficulty in assessing the effects of fish culture on water quality in Spring Creek and the Ironton Canal.

Comparison of stations 1 and 2 with 3 revealed that degrading loads of nutrients were added to the water system by the State hatchery. Changes in M.O. alkalinity, total hardness, total dissolved solids, nitrates, ammonia, dissolved oxygen and carbon dioxide were indicative of improved water quality. Settleable and suspended solids, turbidity, specific conductance, nitrite, B.O.D., and M.P.N. coliform, increased in concentration which is indicative of degraded water quality.

Statistical analysis revealed that the levels of nitrite, specific conductance, ammonia, B.O.D., M.P.N. coliform, suspended solids, dissolved oxygen, and carbon dioxide were changed significantly by State hatchery activities. These changes were indicative of an increased nutrient load and degraded water quality.

The Federal hatchery outfalls, numbered 5, 10 and 11, when compared to station 1 showed that settleable and suspended solids, turbidity, nitrites, ammonia, B.O.D., M.P.N. coliform, and dissolved oxygen were changed, indicating degraded water quality. Station 12 was the outfall from the lower fingerling pond. The results from this sampling point were similar to the other Federal hatchery outfalls except that dissolved oxygen content of the water supply was increased while passing through the pond.

The receiving waters separated into two branches, Ironton Canal and Spring Creek, represented by stations 4, 6, 7 and 4, 13 and 14, respectively. Settleable and suspended solids, ammonia, B.O.D., and M.P.N. coliform increased in the Ironton Canal. Statistical analysis were conducted on the changes made by the Federal hatchery on the Ironton Canal and Spring Creek. Turbidity, ammonia, B.O.D., M.P.N. coliform, suspended solids, dissolved oxygen and carbon dioxide were changed significantly (Table 1). These changes suggest a hygenic degradation and eutrophication of the water in this branch of Spring Creek.

On Spring Creek proper there was a significant increase in nitrites, settleable solids, turbidity, ammonia, B.O.D., M.P.N. coliform, suspended solids and total dissolved solids. A decrease in carbon dioxide occurred between station 4 and the lower comparison station 14. These changes indicated a degradation of water quality in Spring Creek.

Bottom fauna analysis also indicated that the hatcheries were degrading the water. The difference in numbers and quality of organisms found between stations 1 and 4 indicated a poorer water quality through the State hatchery. The comparison of stations 4 to 7 and 4 to 14 shows a recovery from the degraded quality at station 4. However, it is noted that the

State outfall constitutes the source of receiving water for the Federal hatchery and the Federal hatchery further degrades this water by addition of the effluent to the stream. Chemical comparison of station 1 with stations 5, 10 and 11 indicates lower quality water is released from the Federal hatchery.

Figures 217 and 218 show the relationship of the food used and the number of fish raised at the Springville State and Federal hatcheries. As in the hatcheries previously considered, there was no observable correlation between degradation of the water and the number of fish present and food used.

CONCLUSIONS

Fish cultural activities caused a progressive degradation of water quality in the hatchery system which when added to the receiving water, caused subsequent degradation of the receiving water. The effect of this degradation was closely correlated with the quality of water prior to hatchery use. A high quality water showed the degradation less than a water of lower quality.

Kamas and Loa had this high quality water available for hatchery use and the receiving waters were not degraded significantly. The water supplies of the other hatcheries studied showed a high degree of enrichment before use and when the hatchery wastes were added, resulted in degradation which could be quite serious from a public health standpoint.

In all but the Kamas and Midway hatcheries the M.P.N. coliform counts increased significantly as a result of hatchery activities. This increase might be interpreted as a potential hazard to public health of the area. The counts, however, may not have the impact as initially evident because the levels were determined by "Standard Methods Multiple-Tube Fermentation Technique" which gives results of all organisms present which produce gas on lactose fermentation. The tests performed report not only human fecal contamination but also contributions from fish and animal excrement, fish food, soil and many other sources. Since fish are not suspect of adding greatly to the coliform levels and food is suspect of contributing only a minor portion to these high concentrations, other sources are probably responsible for this large increase. Further studies should be conducted to determine the sources of the high coliform levels.

B.O.D. levels were increased significantly through hatchery activities at all installations except Midway. The highest concentrations were found at the commercial hatchery which utilized a combination of animal offal fed wet, and dry pelleted food.

The use of wet animal offal for fish food increased the potential for degrading the water in the hatchery and the receiving waters. Incomplete utilization by fish left residues which subsequently decayed in the raceways and increased enrichment to a point that severe degradation of the receiving water occurred. When pelleted food was fed exclusively, most of the food was consumed immediately as seen in lower B.O.D. concentrations and concomitant parameter levels in hatcheries using pelleted food.

The enrichment of the receiving waters by hatchery activities has increased the growth and propagation of many fish food organisms. This situation from a fishery point of view is probably desirable. However, this enrichment when evaluated from public health and a water quality standpoint may not be desirable.

BIBLIOGRAPHY

American Public Health Association Ins., et al."Standard Methods for the Examination of Water and Wastewater." Twelfth edition. Boyd Printing Company, Inc., Albany, N. Y. 1965.

Alabaster, J. S., and Herbert, D. M., "Influence of Carbon Dioxide on the Toxicity of Ammonia," *Nature* 174:404, 1954.

Bean, E. L., "Development of Water Quality Ideals," Jour. A.W.W.A. 53:1361, 1961.

Brockway, D. R., "Metabolic Products and Their Effects," *Progressive Fish Culturist*, 12:3, pp. 127-129, 1950.

Davis, H. S., *Culture and Diseases of Game Fishes*, University of California Press, pp. 185-186, 1956.

Gaufin, A. R., and Tarzwell, C. M., "Aquatic Insects as Indicators of Stream Pollution," *Public Health Reports*, 67:1, pp. 59-64, 1952.

Gaufin, A. R., and Tarzwell, C. M., "Aquatic Macro-Invertebrate Communities as Indicators of Organic Pollution in Lytle Creek," *Sewage and Industrial Wastes*, 28:7, pp. 906-924, 1956.

Grantham, B. J., "The Value and Use of Macro-Invertebrates in Evaluating Stream Pollution Conditions," Proceedings Mississippi Water Resources Conference, 1966.

Hinshaw, R. N., "The Pollutional Degradation of the Jordan River as Shown by Aquatic Invertebrates," Utah Fish and Game publication number 66-11, 1966.

Lloyd, R., and Herbert, D. W. M., "The Influence of Carbon Dioxide on the Toxicity of Un-Ionized Ammonia to Rainbow Trout (*Salmo gairdnerii* Richardson)." *Ann. Appl. Biol*. 48:339, 1960.

Needham, J. G., and Needham, P. R., "Fresh Water Biology," Holden Day Inc., San Francisco, California, 1966.

State of Washington, "Toxic Effects of Organic and Inorganic Pollutants on Young Salmon and Trout," Bulletin number 5, pp. 183-187, 1960.

Tabata, K., "Toxicity of Ammonia to Aquatic Animals with Reference to the Effect of pH and Carbon Dioxide," *Bull. Tokai, Reg. Fish., Res. Lab*. 34, pp. 67-74, 1962; *Biol. Abstr*. 45:755, 1964.

APPENDIX A

PHYSICAL - CHEMICAL DATA

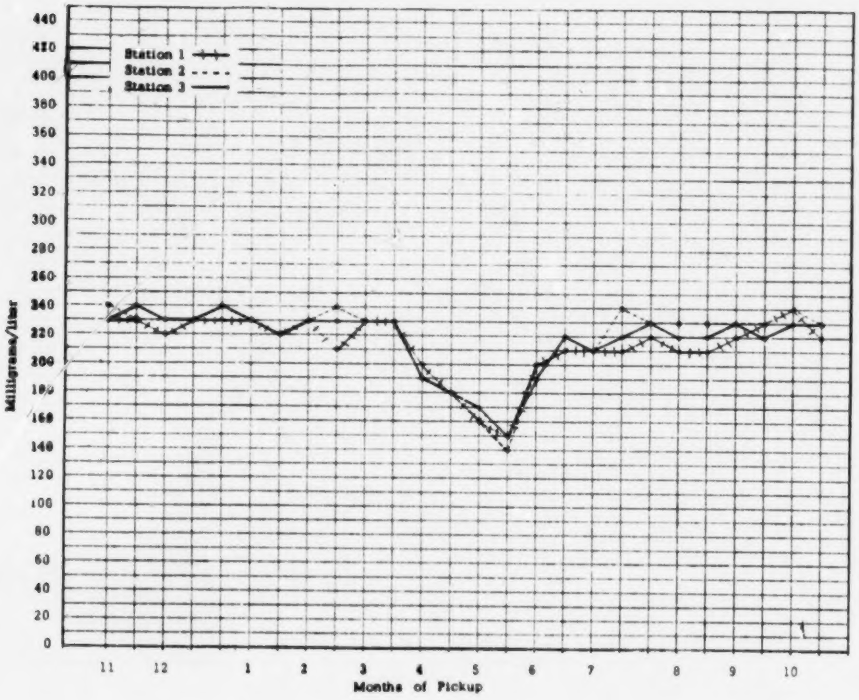

Figure 1. Kamas Hatchery, M.O. Alkalinity. Stations 1, 2 and 3.

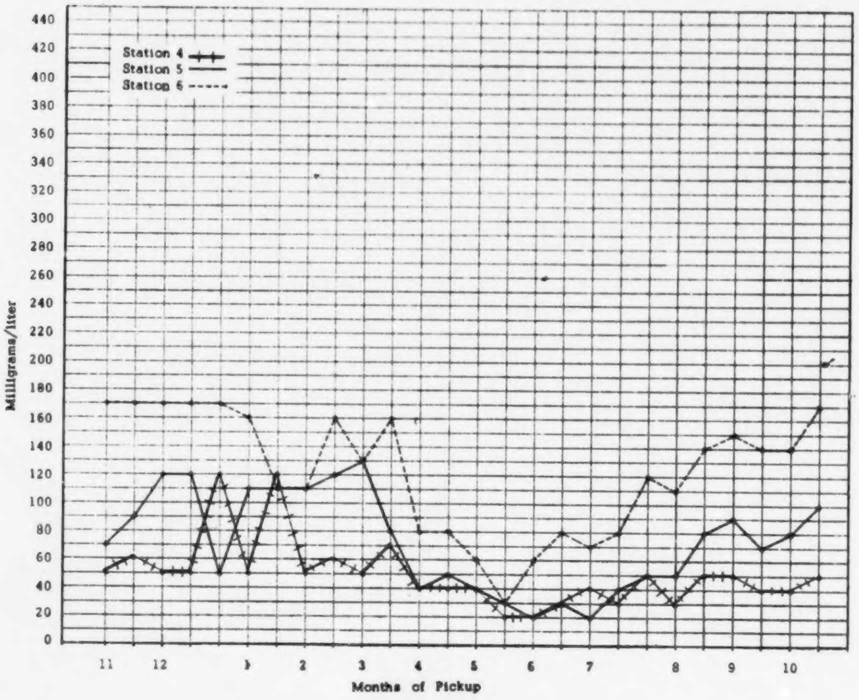

Figure 2. Kamas Hatchery, M.O. Alkalinity. Stations 4, 5 and 6.

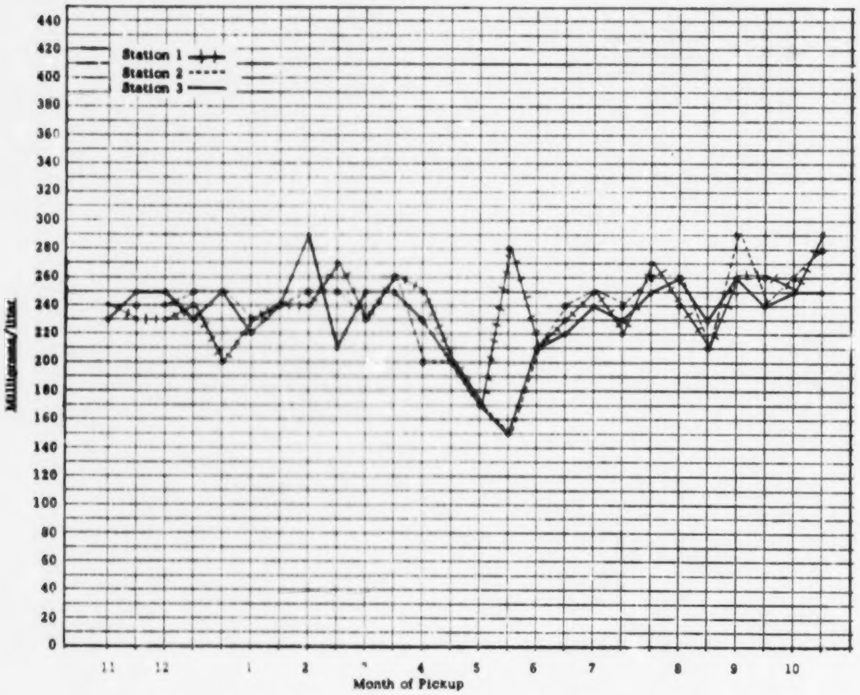

Figure 3. Kamas Hatchery, Total Hardness. Stations 1, 2 and 3.

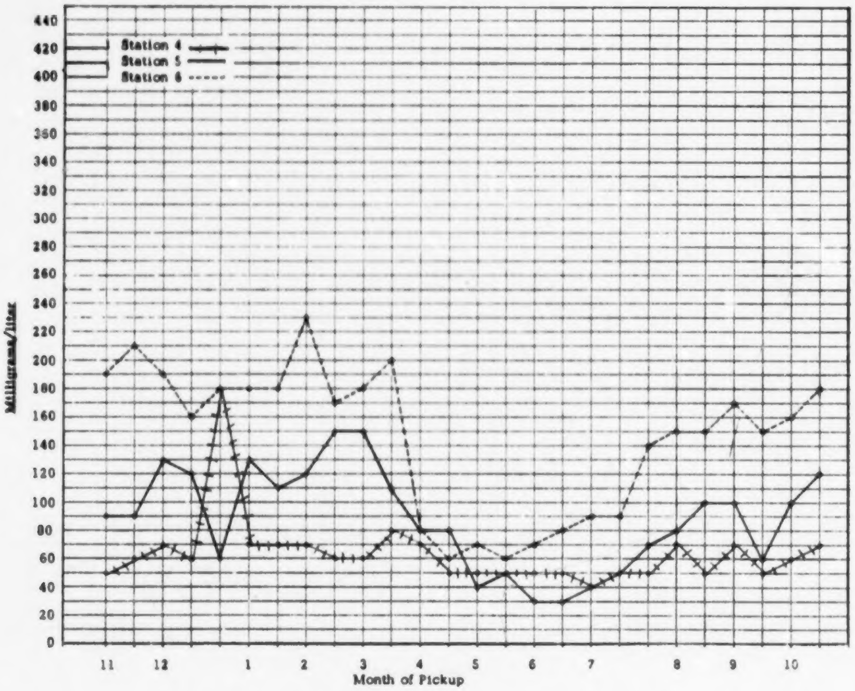

Figure 4. Kamas Hatchery, Total Hardness. Stations 4, 5 and 6.

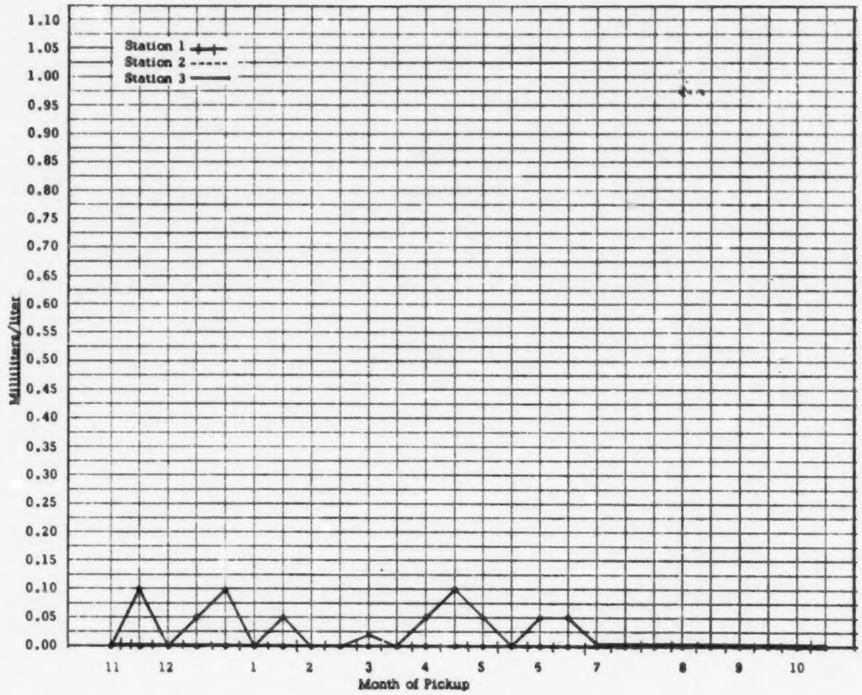

Figure 5. Kamas Hatchery, Settleable Solids. Stations 1, 2 and 3.

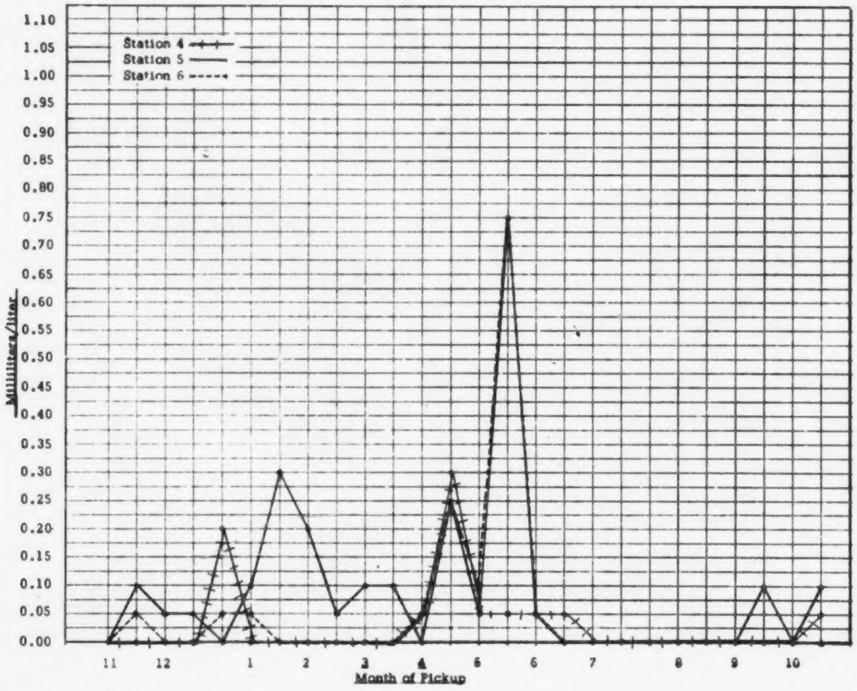

Figure 6. Kamas Hatchery, Settleable Solids. Stations 4, 5 and 6.

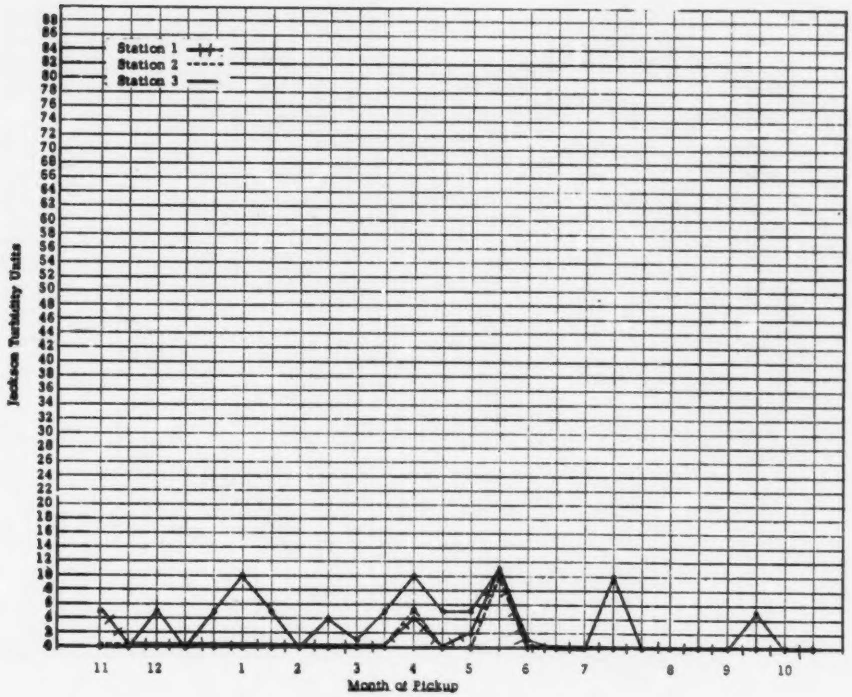

Figure 7. Kamas Hatchery, Turbidity. Stations 1, 2 and 3.

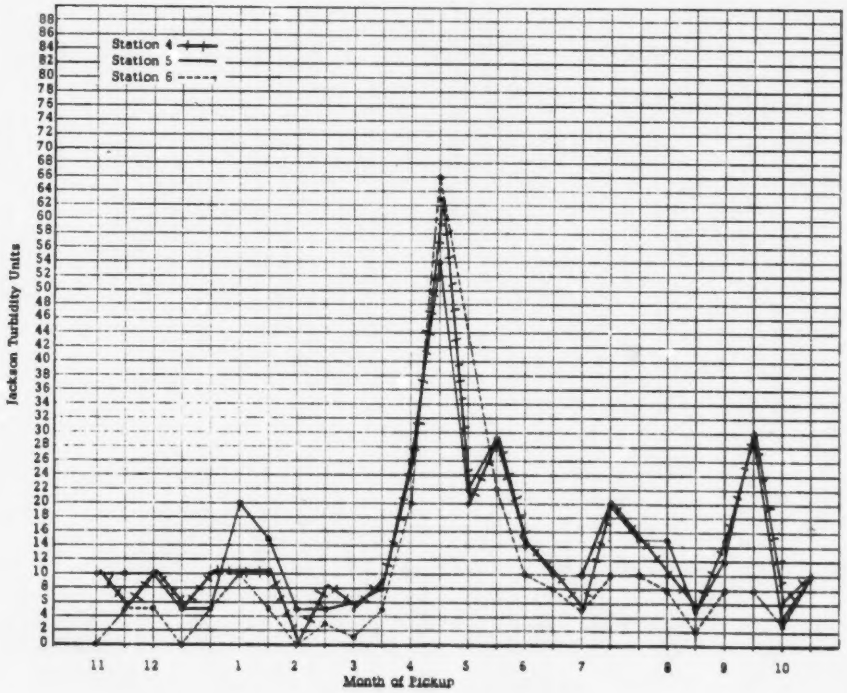

Figure 8. Kamas Hatchery, Turbidity. Stations 4, 5 and 6.

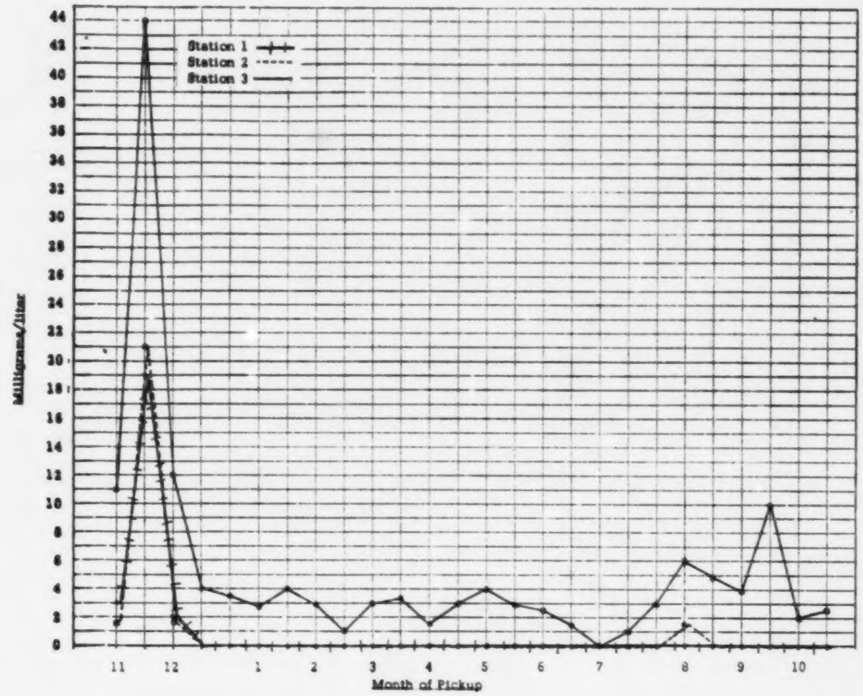

Figure 9. Kamas Hatchery, Suspended Solids. Stations 1, 2 and 3.

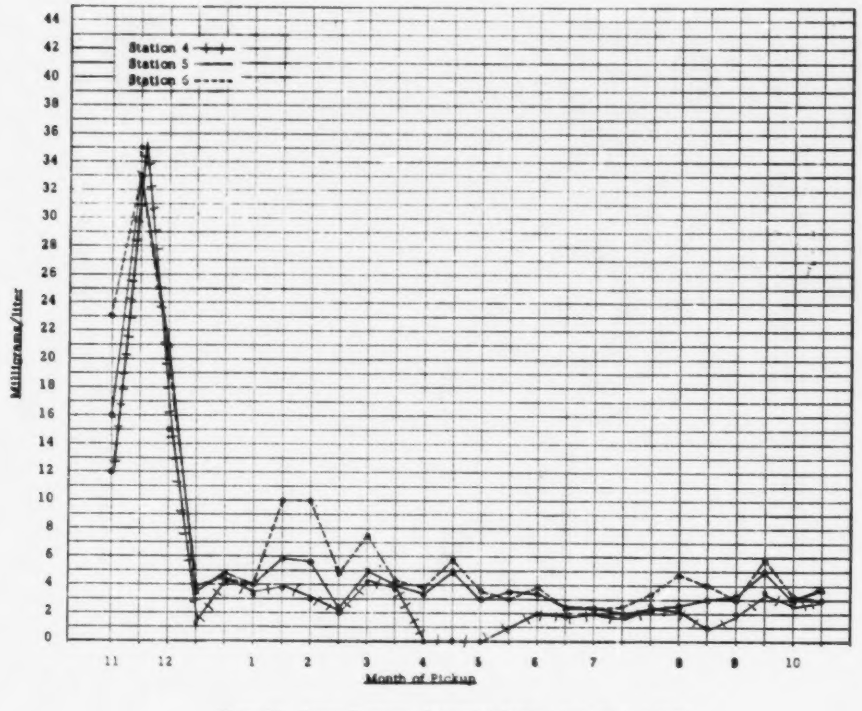

Figure 10. Kamas Hatchery, Suspended Solids. Stations 4, 5 and 6.

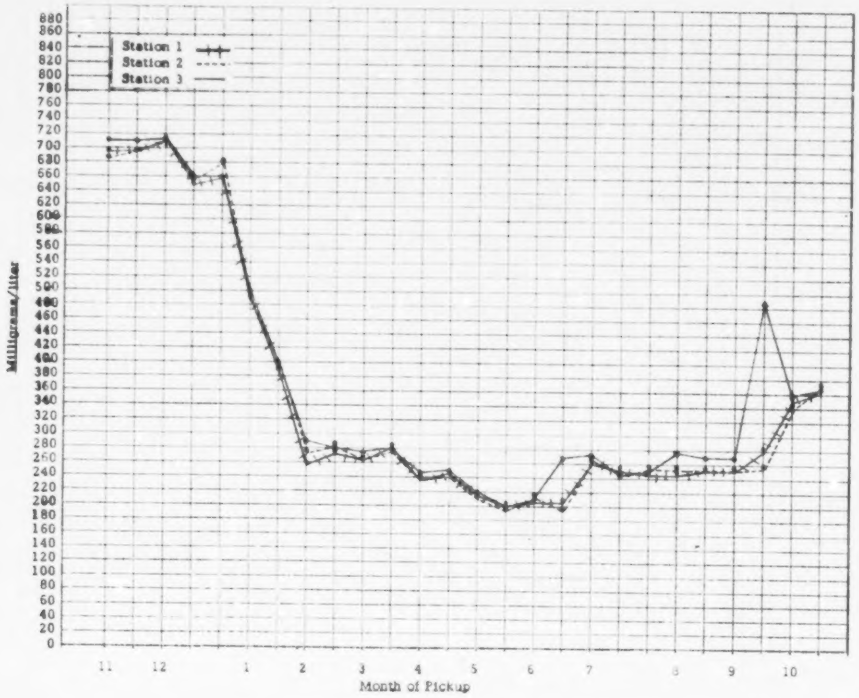

Figure 11. Kamas Hatchery, Total Dissolved Solids. Stations 1, 2 and 3.

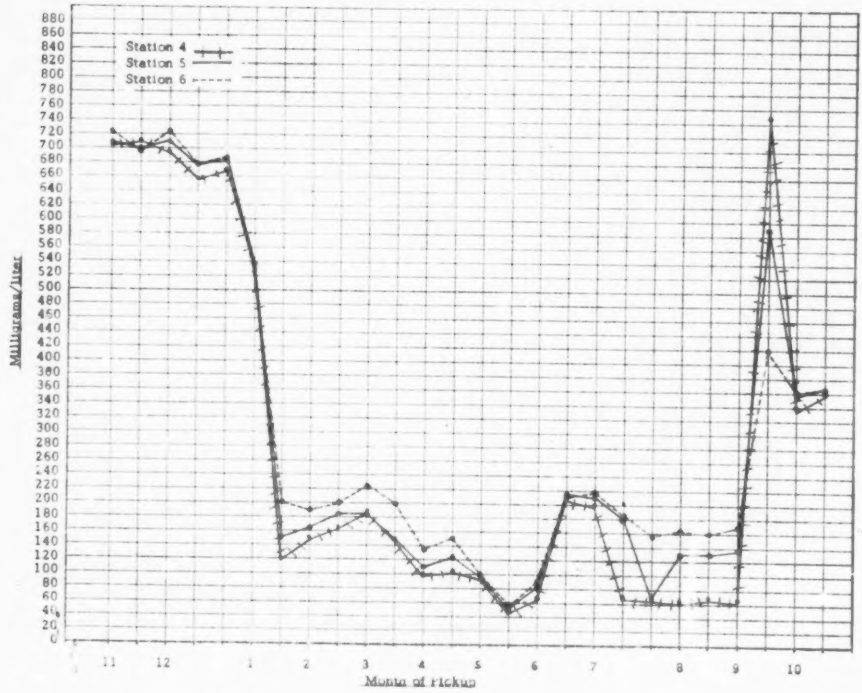

Figure 12. Kamas Hatchery, Total Dissolved Solids. Stations 4, 5 and 6.

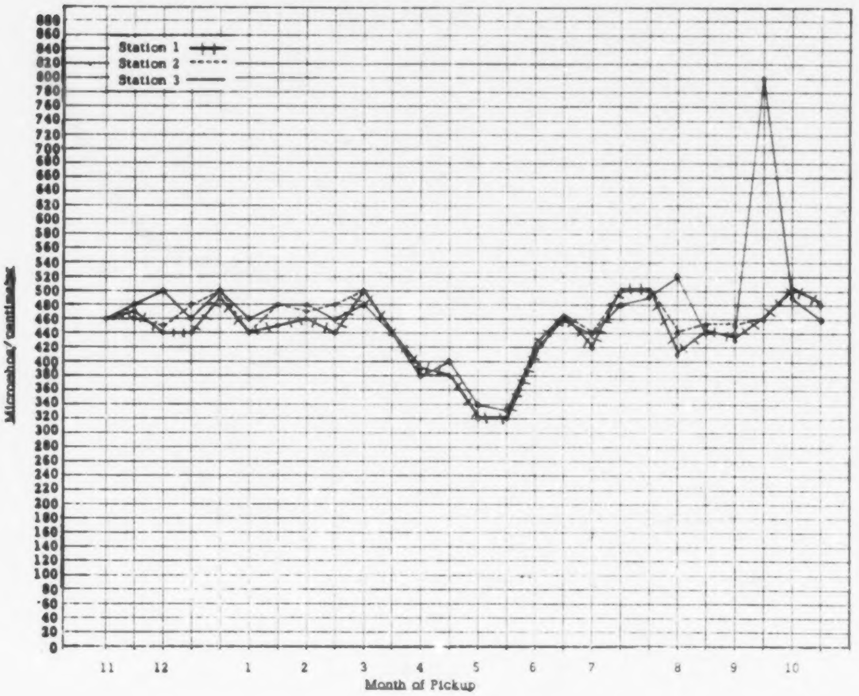

Figure 13. **Kamas** Hatchery, Specific Conductance. Stations 1, 2 and 3.

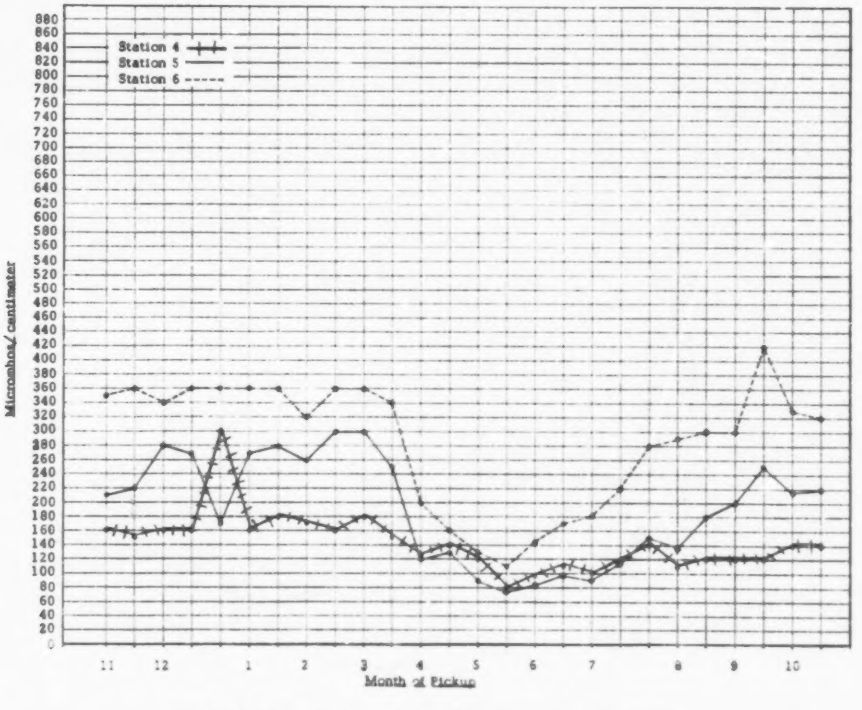

Figure 14. Kamas Hatchery, Specific Conductance. Stations 4, 5 and 6.

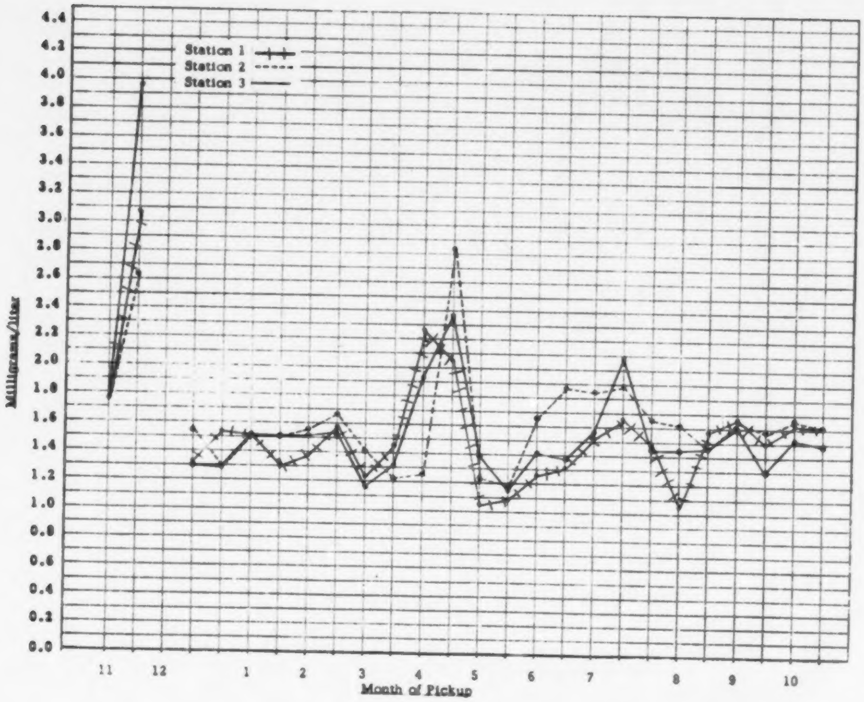

Figure 15. Kamas Hatchery, Nitrate. Stations 1, 2 and 3.

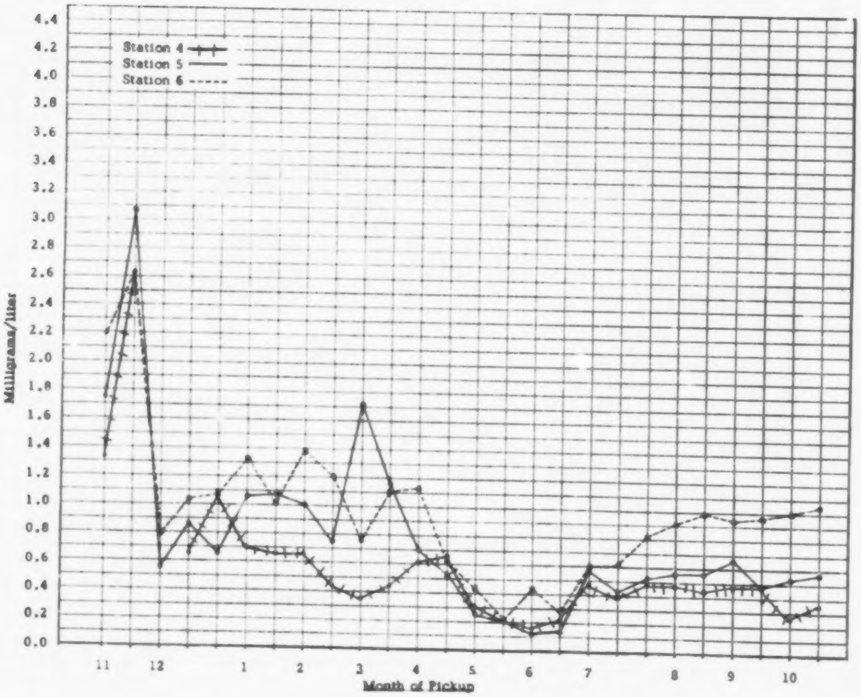

Figure 16. Kamas Hatchery, Nitrate. Stations 4, 5 and 6.

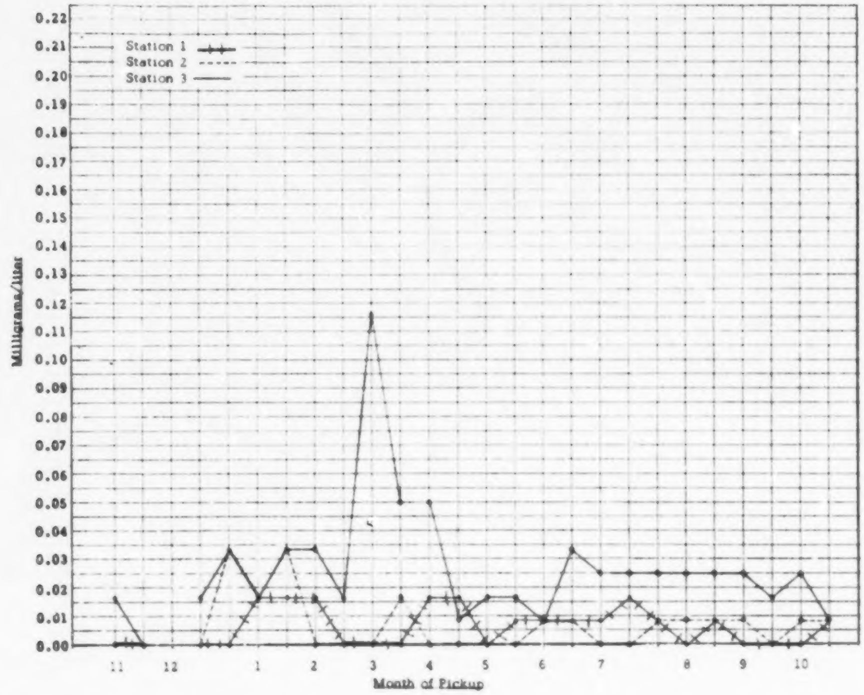

Figure 17. Kamas Hatchery, Nitrite, Stations 1, 2 and 3.

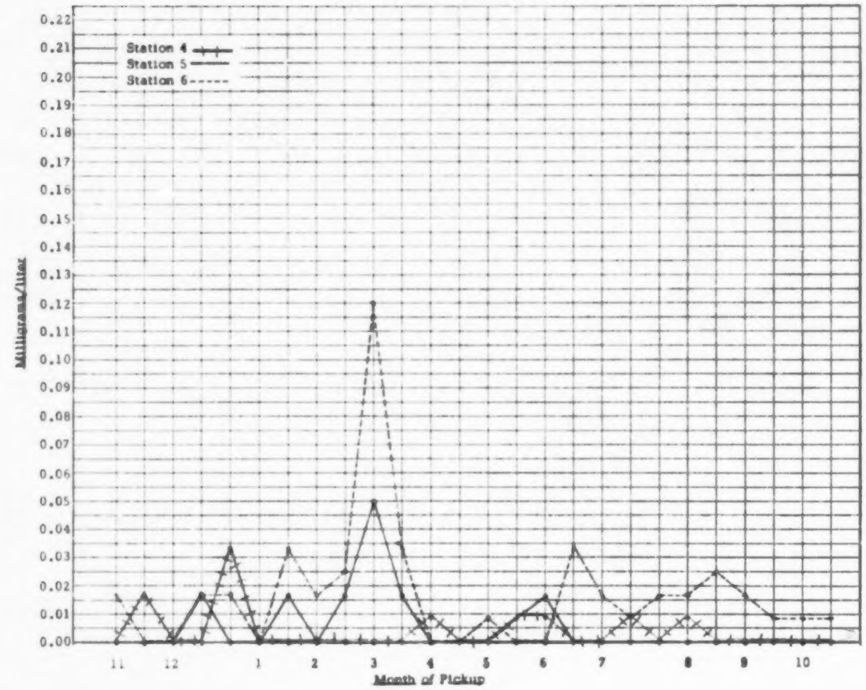

Figure 18. Kamas Hatchery, Nitrite, Stations 4, 5 and 6.

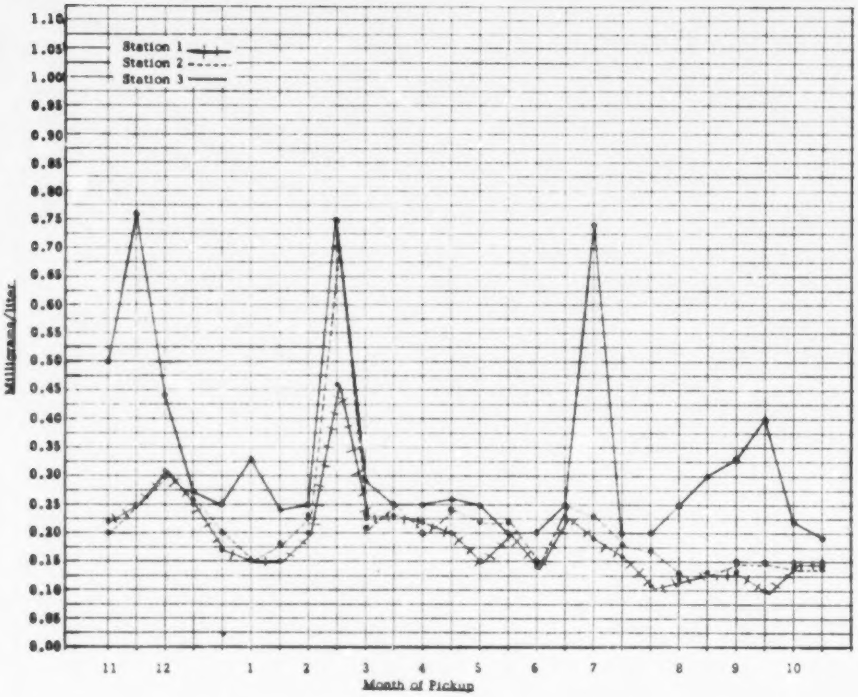

Figure 19. Kamas Hatchery, Ammonia. Stations 1, 2 and 3.

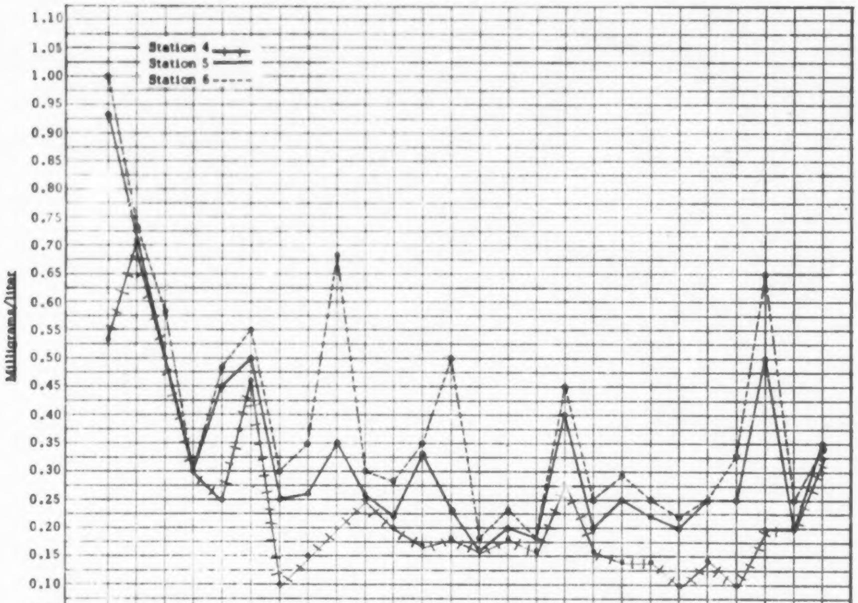

Figure 20. Kamas Hatchery, Ammonia. Stations 4, 5 and 6.

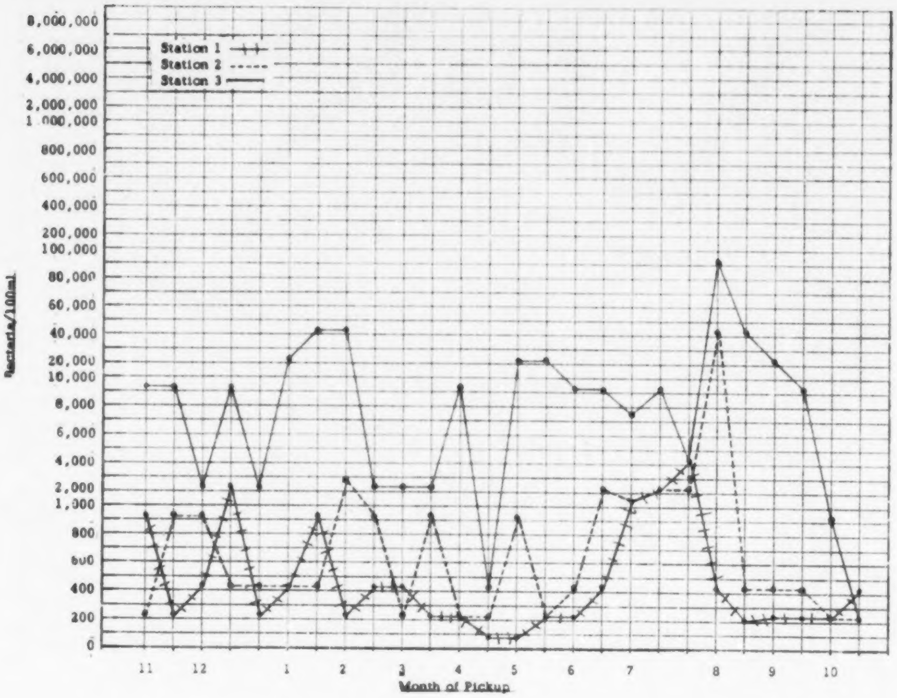

Figure 21. Kamas Hatchery, MPN Coliform, Stations 1, 2 and 3.

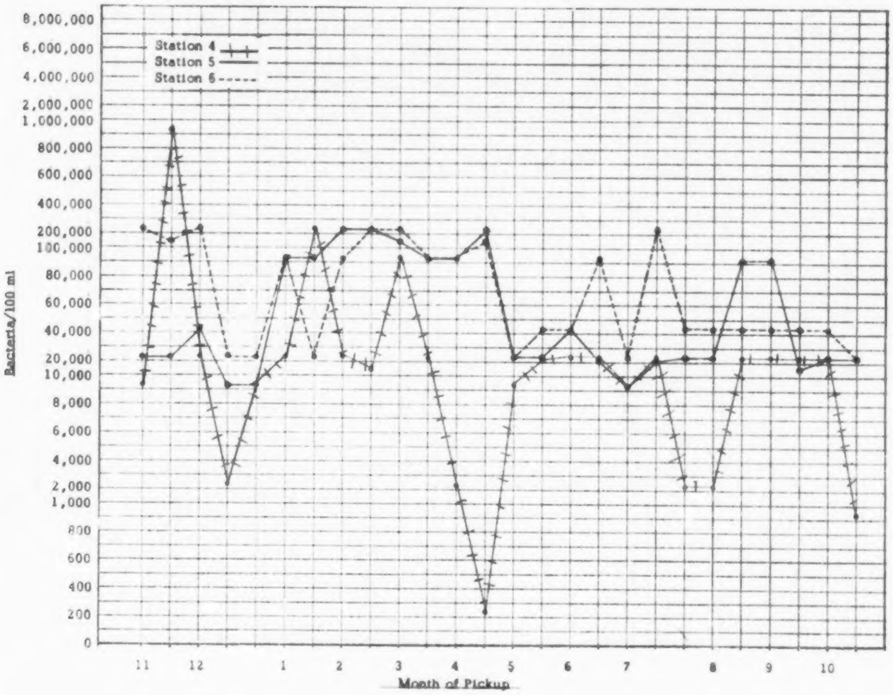

Figure 22. Kamas Hatchery, MPN Coliform, Stations 4, 5 and 6.

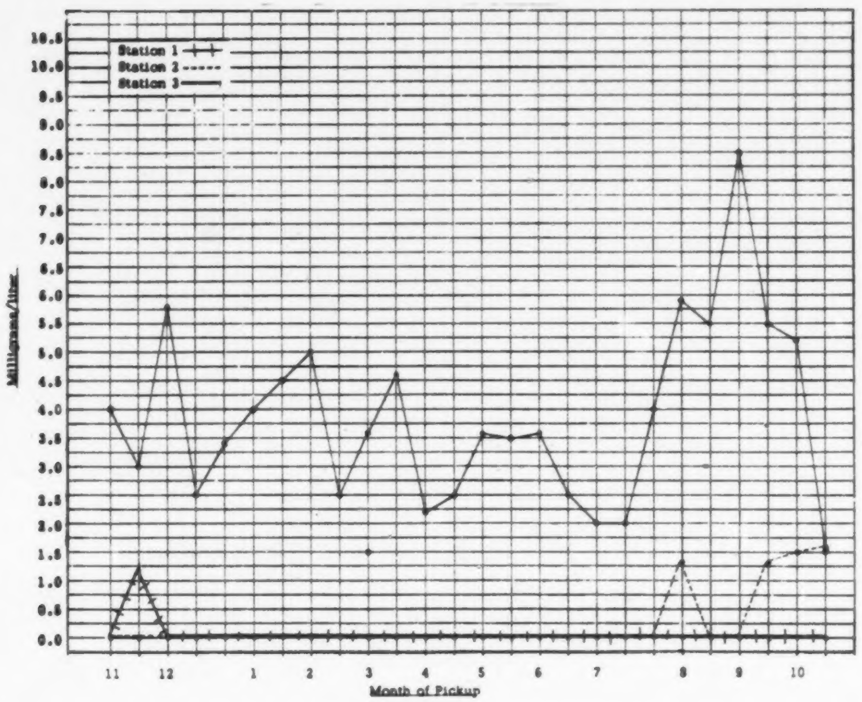

Figure 23. Kamas Hatchery, Biochemical Oxygen Demand. Stations 1, 2 and 3.

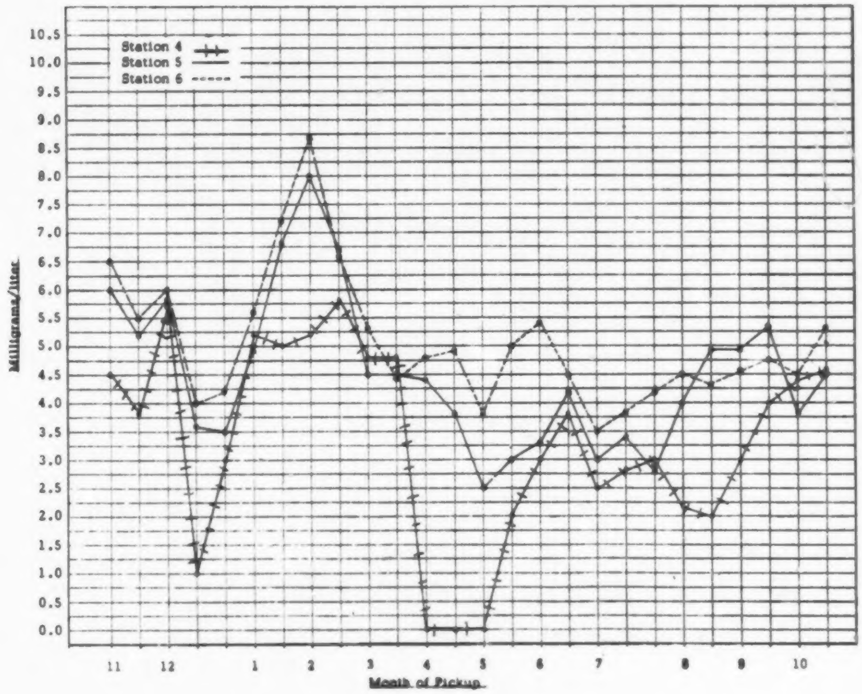

Figure 24. Kamas Hatchery, Biochemical Oxygen Demand. Stations 4, 5 and 6.

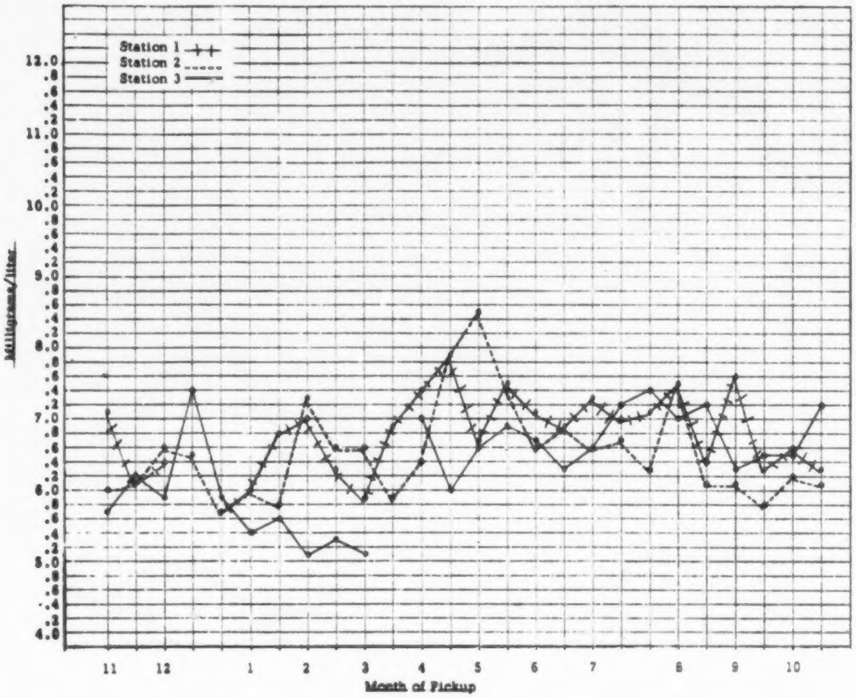

Figure 25. Kamas Hatchery, Dissolved Oxygen. Stations 1, 2 and 3.

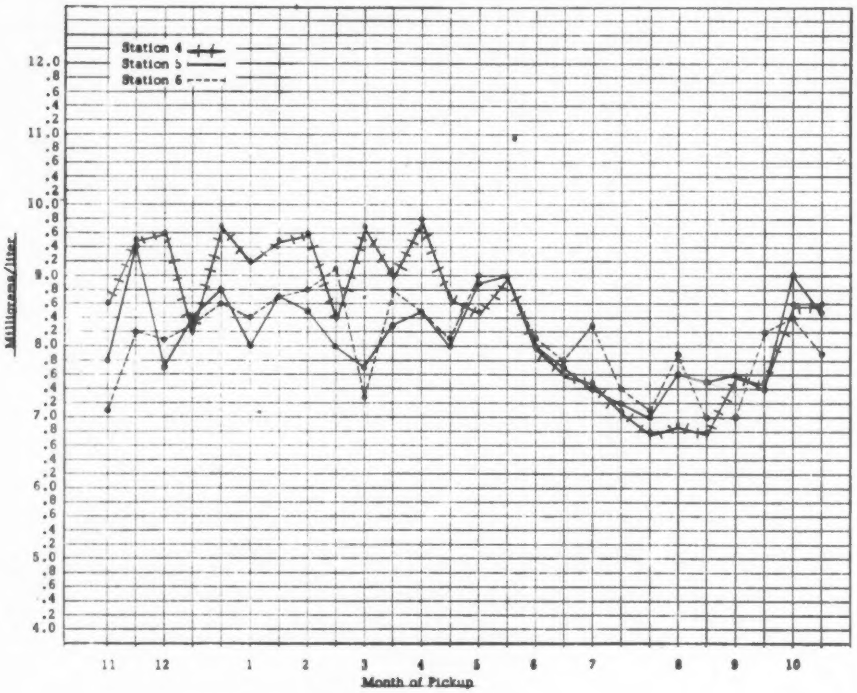

Figure 26. Kamas Hatchery, Dissolved Oxygen. Stations 4, 5 and 6.

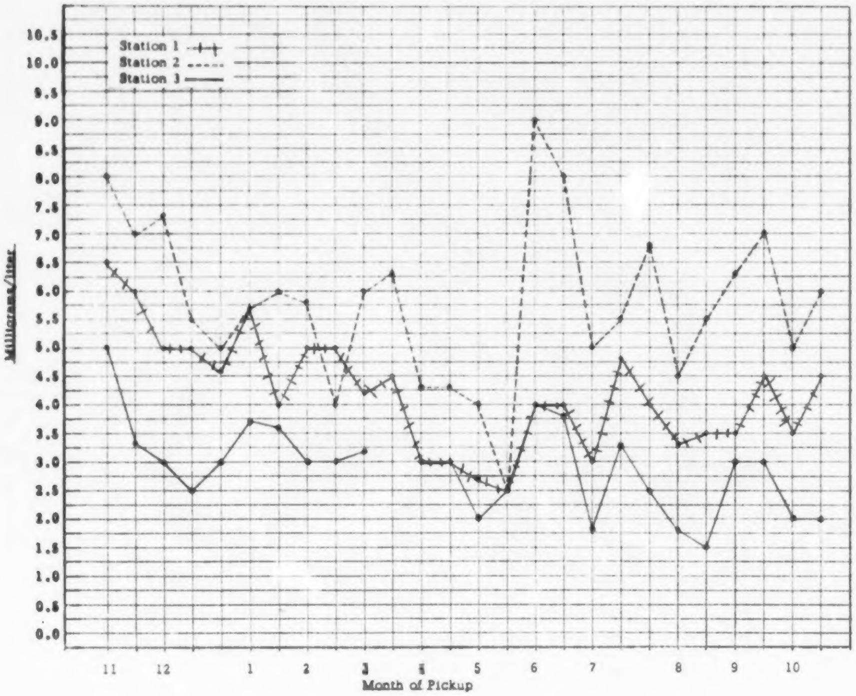

Figure 27. Kamas Hatchery, Carbon Dioxide. Stations 1, 2 and 3.

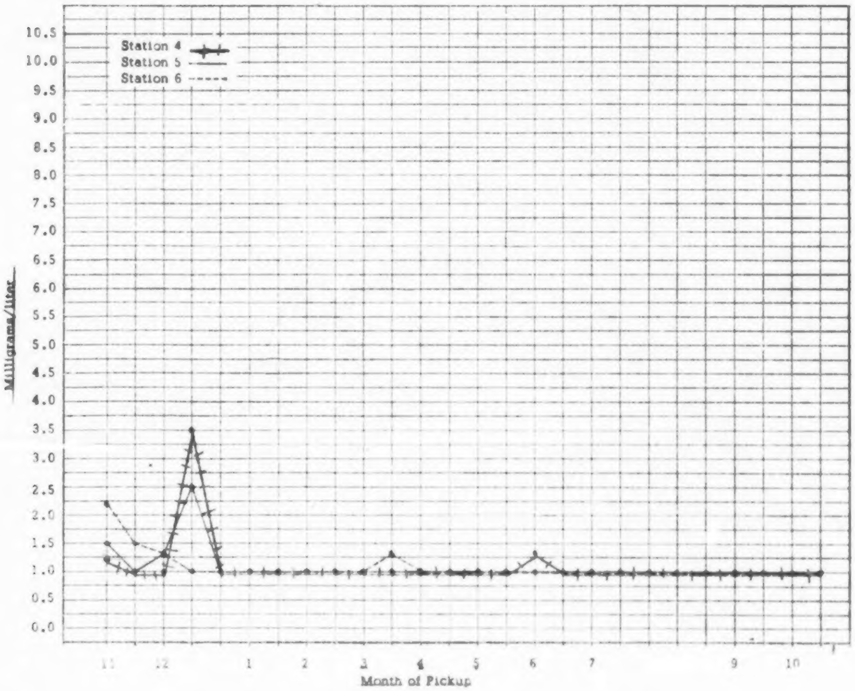

Figure 28. Kamas Hatchery, Carbon Dioxide. Stations 4, 5 and 6.

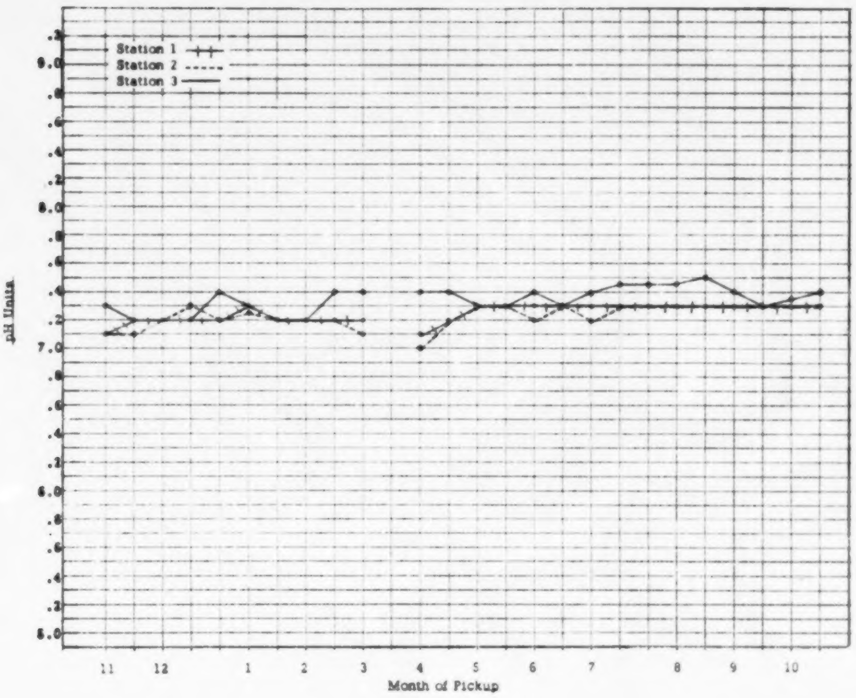

Figure 29. Kamas Hatchery, Hydrogen Ion Concentration. Stations 1, 2 and 3.

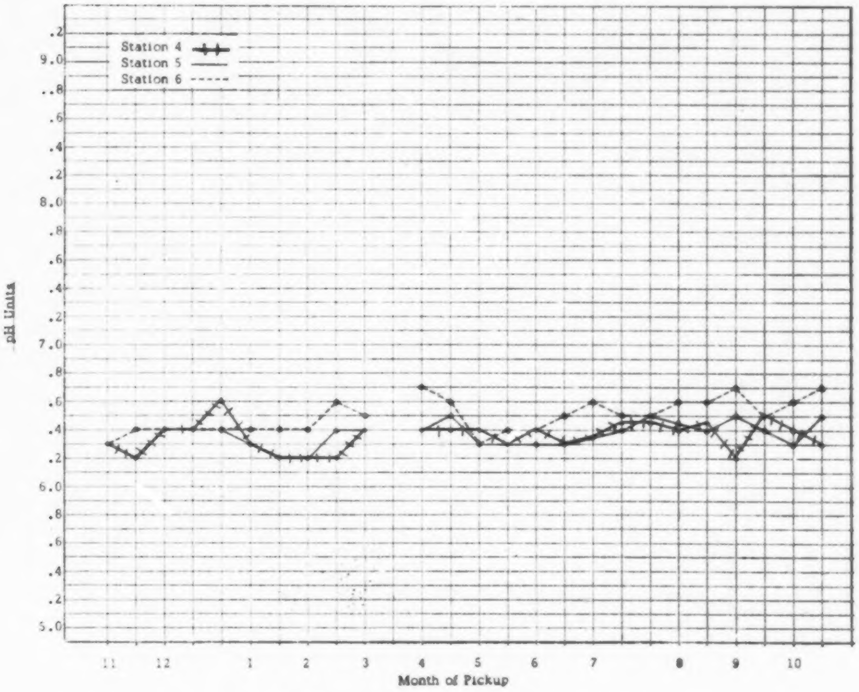

Figure 30. Kamas Hatchery, Hydrogen Ion Concentration. Stations 4, 5 and 6.

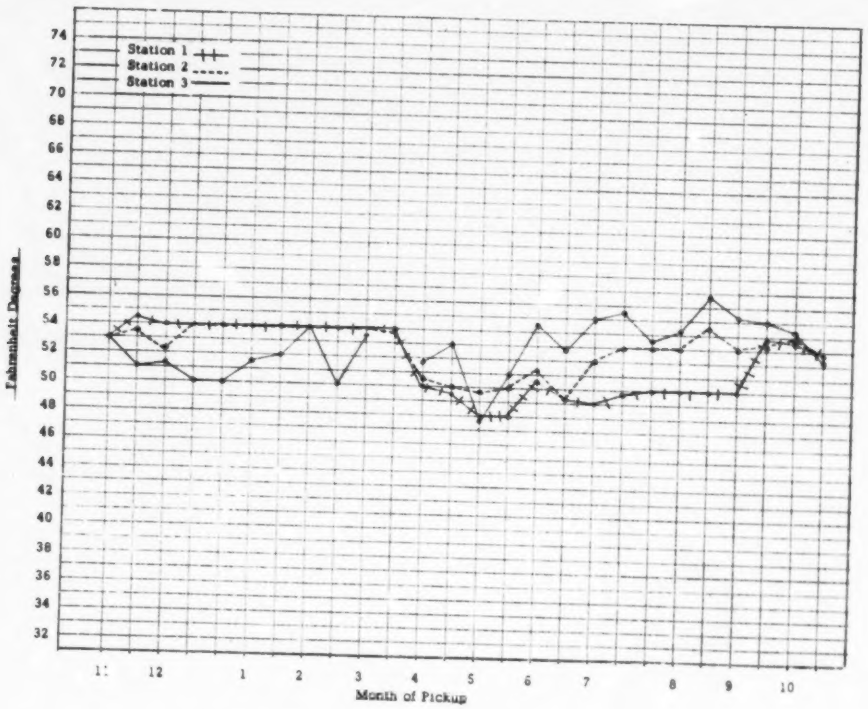

Figure 31. Kamas Hatchery, Temperature. Stations 1, 2 and 3.

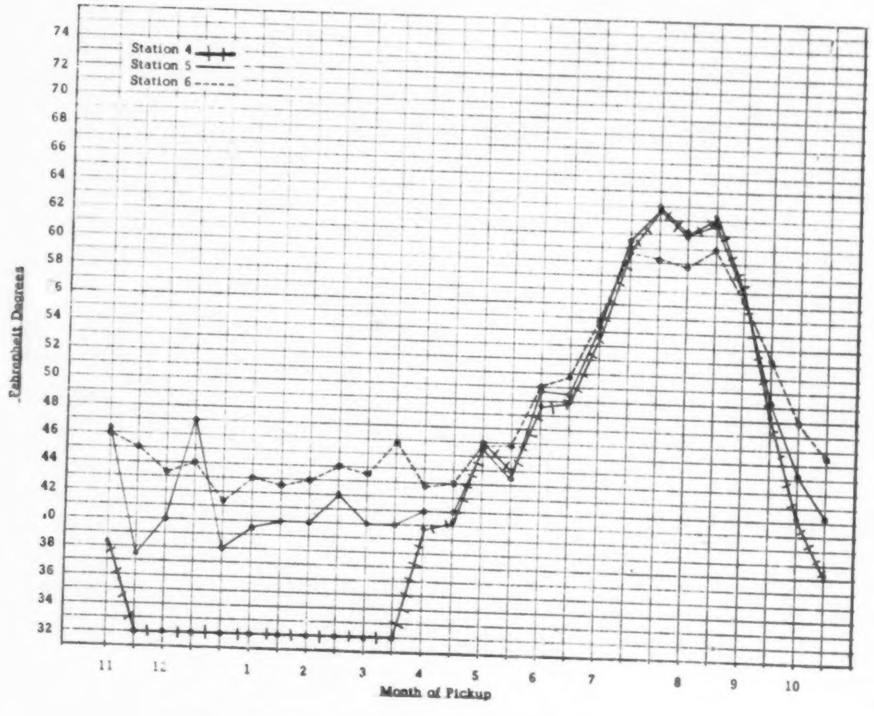

Figure 32. Kamas Hatchery, Temperature. Stations 4, 5 and 6.

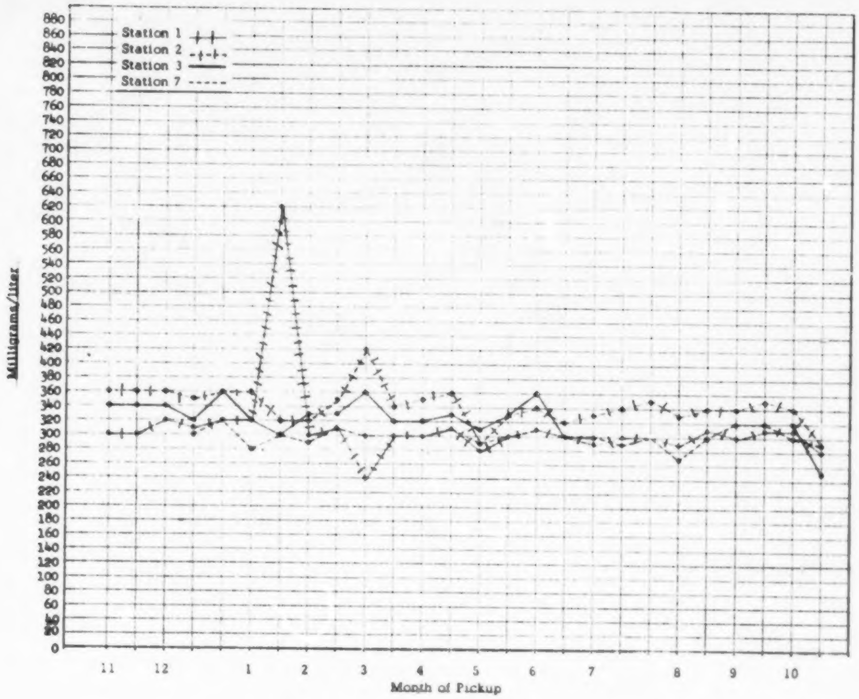

Figure 33. Midway Hatchery. M.O. Alkalinity. Stations 1, 2, 3 and 7.

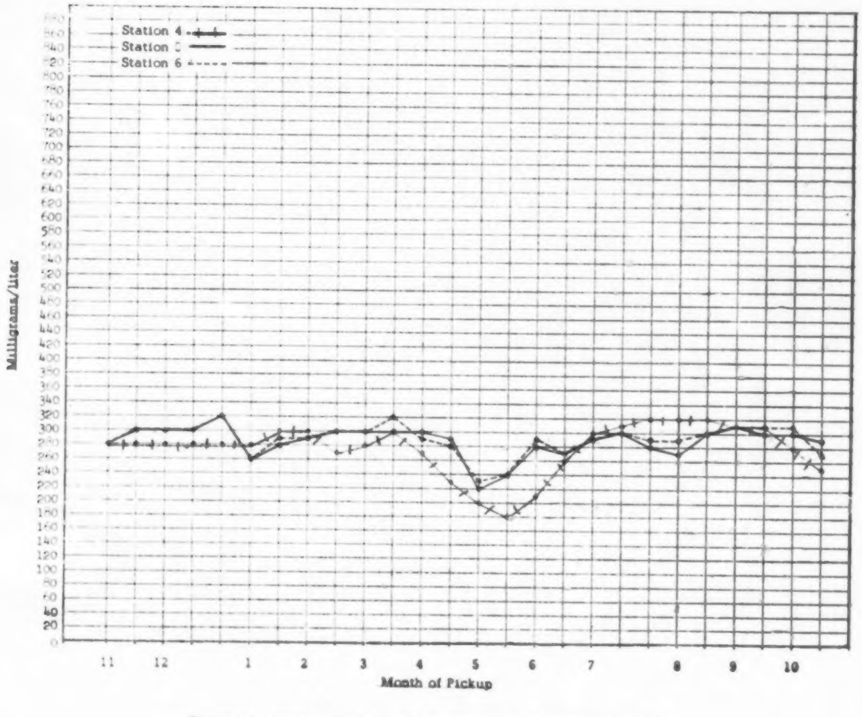

Figure 34. Midway Hatchery. M.O. Alkalinity. Stations 4, 5 and 6.

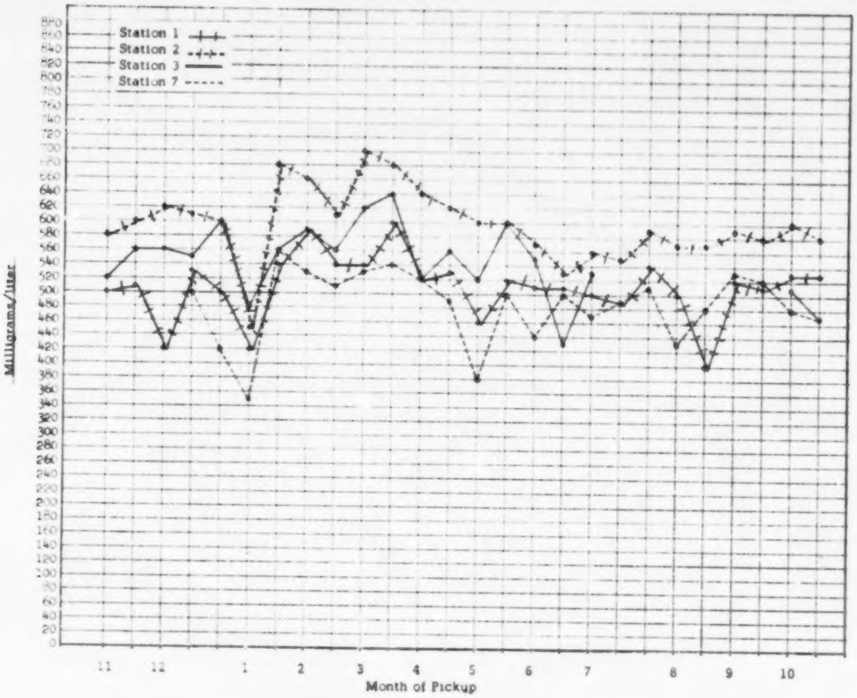

Figure 35. Midway Hatchery, Total Hardness, Stations 1, 2, 3 and 7.

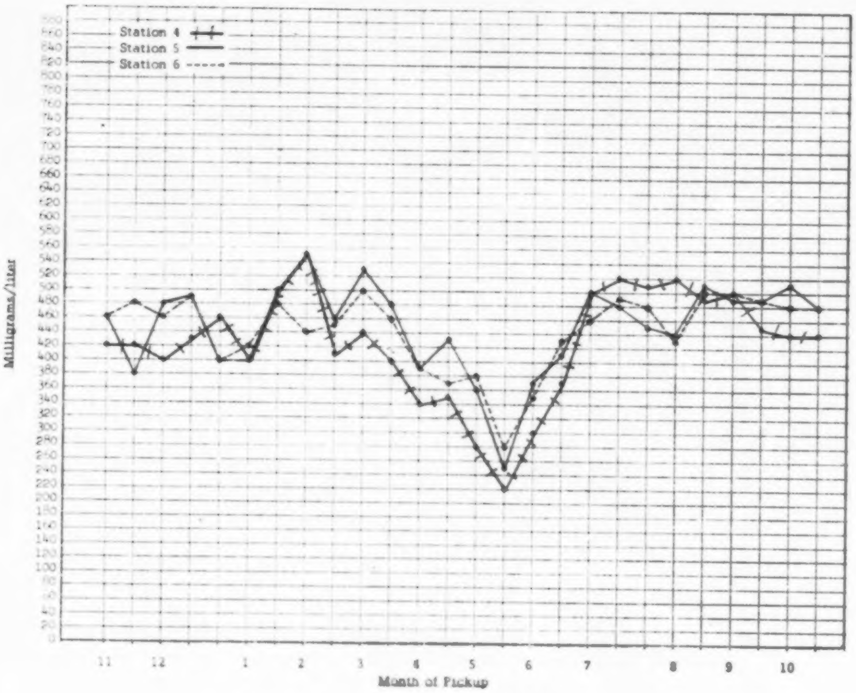

Figure 36. Midway Hatchery. Total Hardness, Stations 4, 5 and 6.

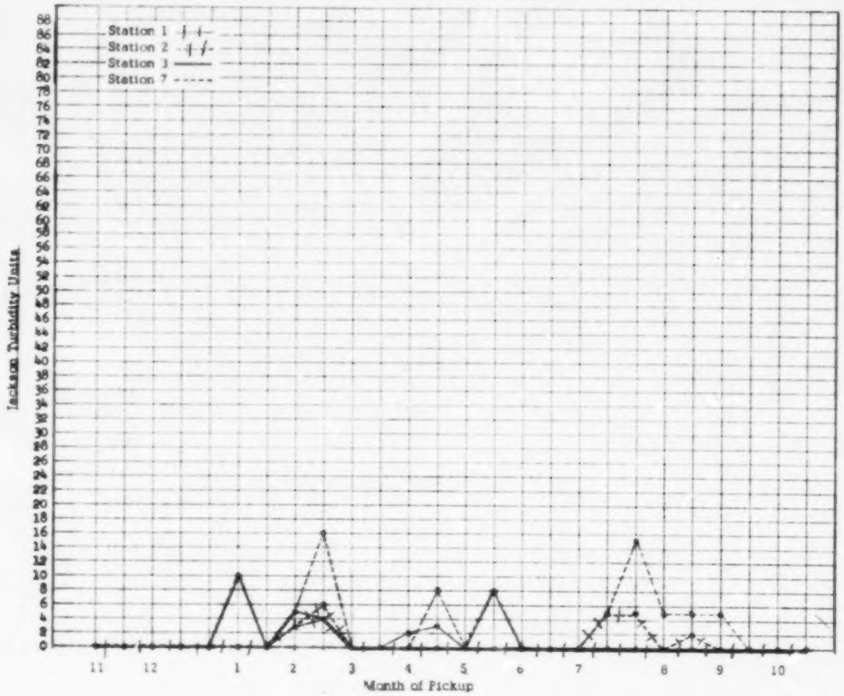

Figure 37. Midway Hatchery. Turbidity. Stations 1, 2, 3 and 7.

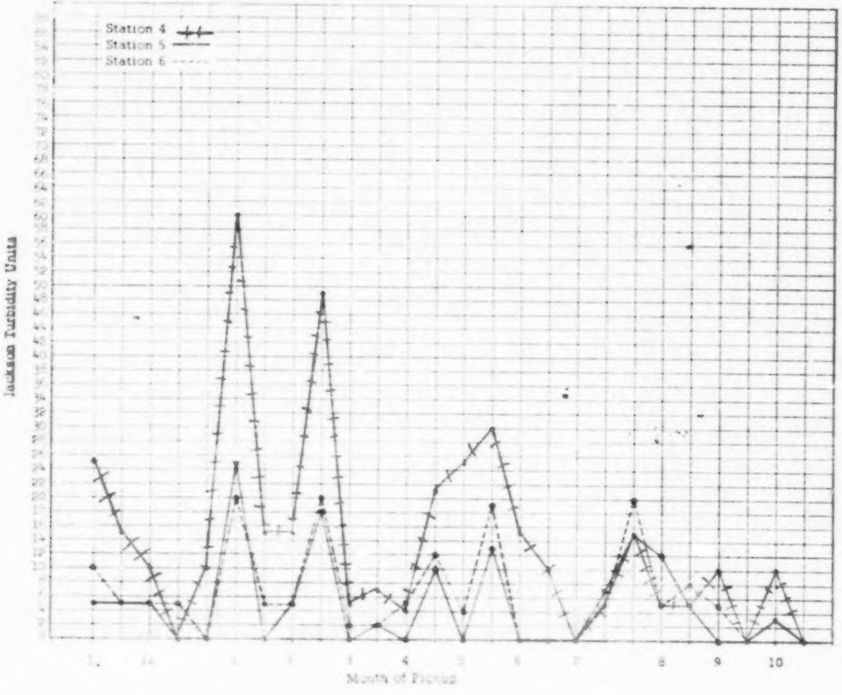

Figure 38. Midway Hatchery. Turbidity. Stations 4, 5 and 6.

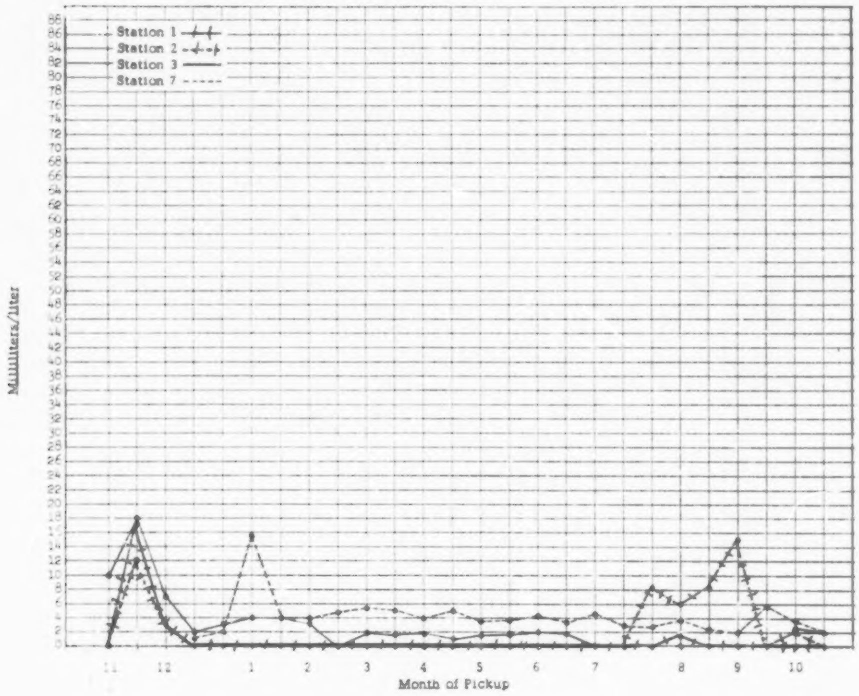

Figure 39. Midway Hatchery, Suspended Solids. Stations 1, 2, 3 and 7.

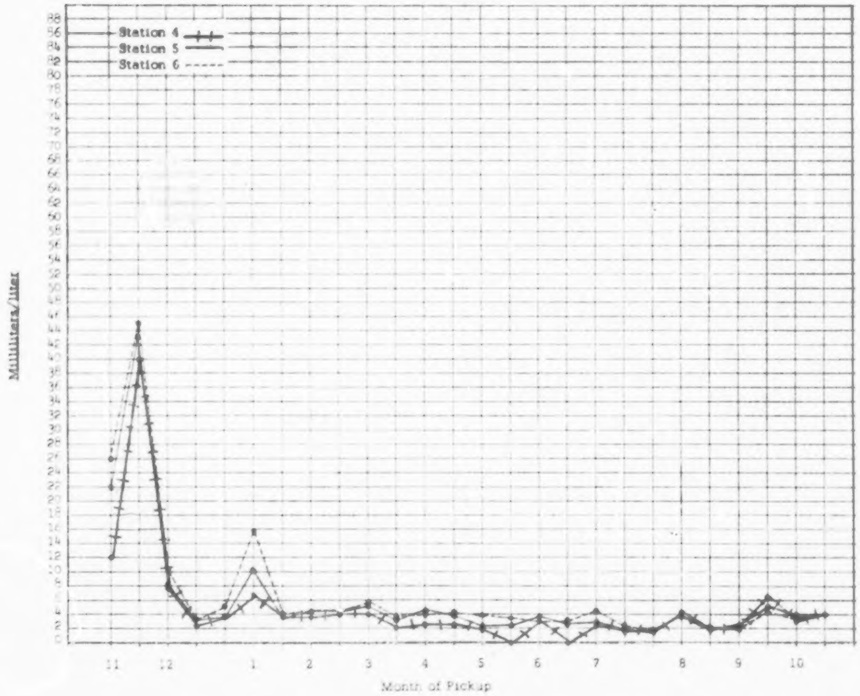

Figure 40. Midway Hatchery, Suspended Solids. Stations 4, 5 and 6.

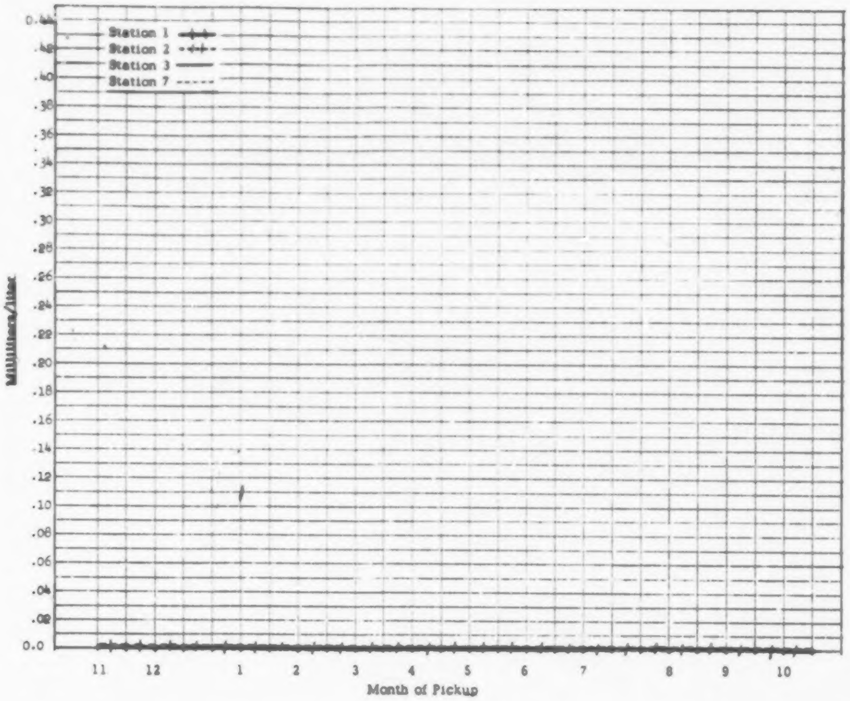

Figure 41. Midway Hatchery, Settleable Solids, Stations 1, 2, 3 and 7.

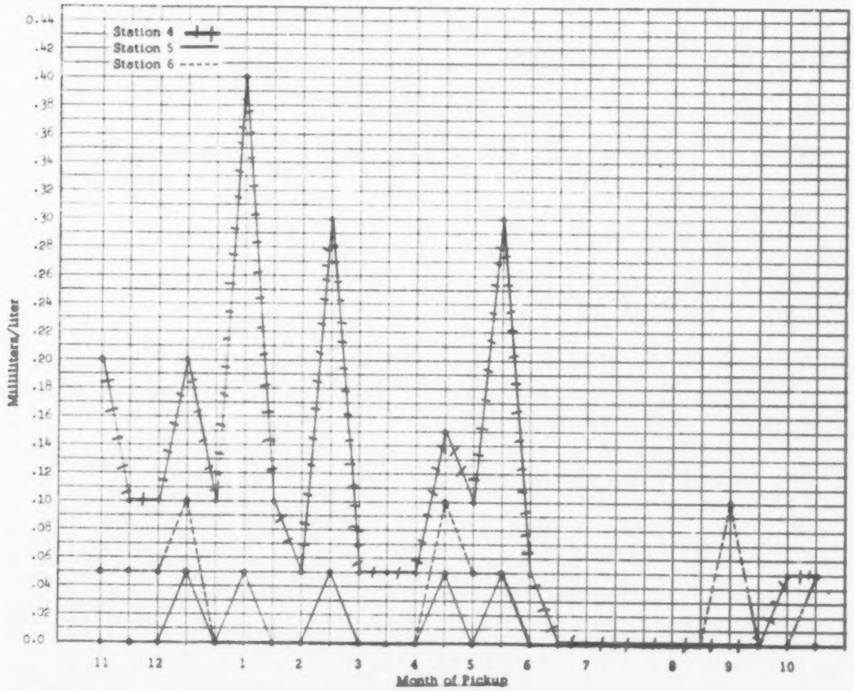

Figure 42. Midway Hatchery, Settleable Solids, Stations 4, 5 and 6.

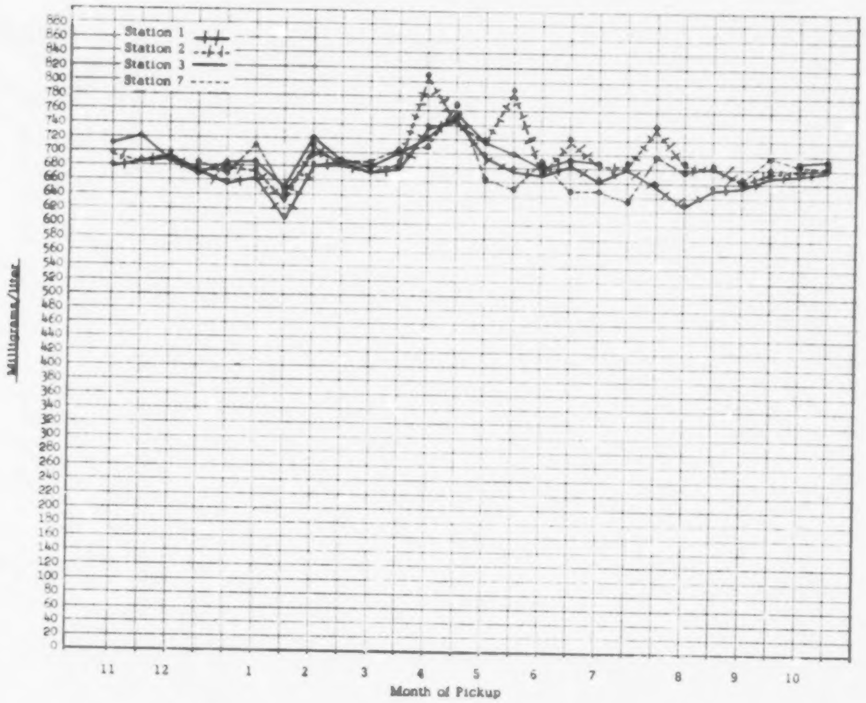

Figure 43. Midway Hatchery. Total Dissolved Solids. Stations 1, 2, 3 and 7.

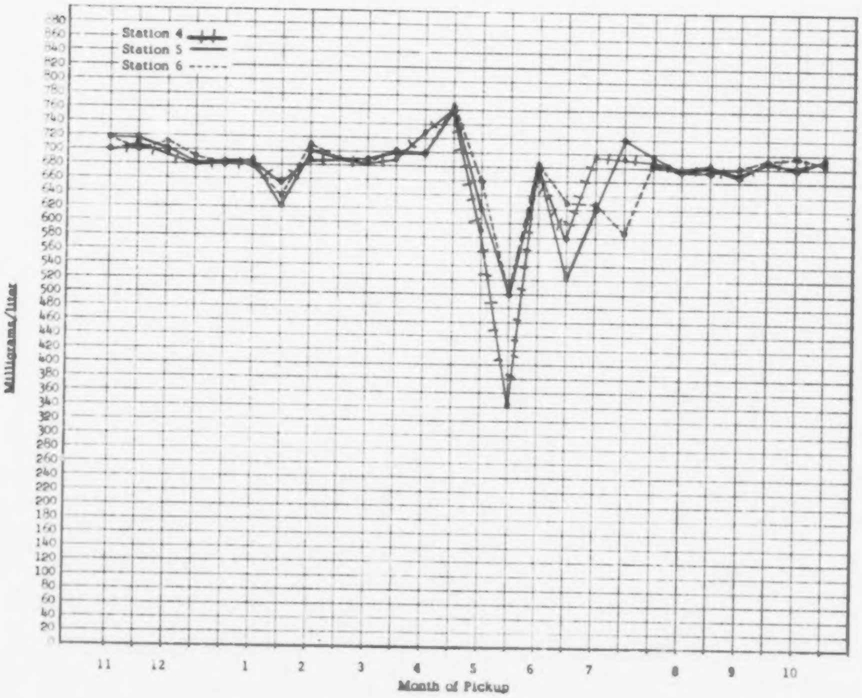

Figure 44. Midway Hatchery. Total Dissolved Solids. Stations 4, 5 and 6.

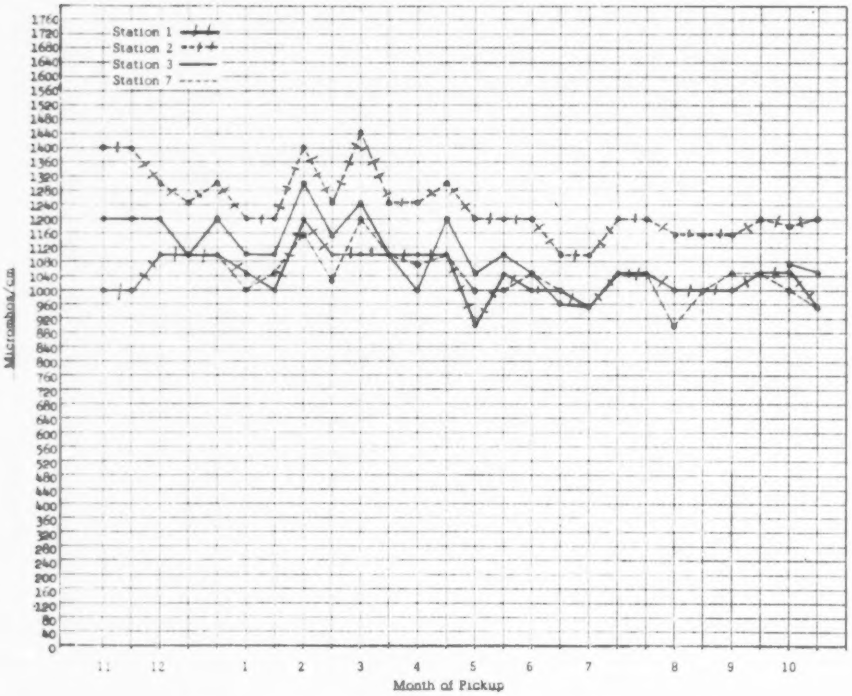

Figure 45. Midway Hatchery, Specific Conductance. Stations 1, 2, 3 and 7.

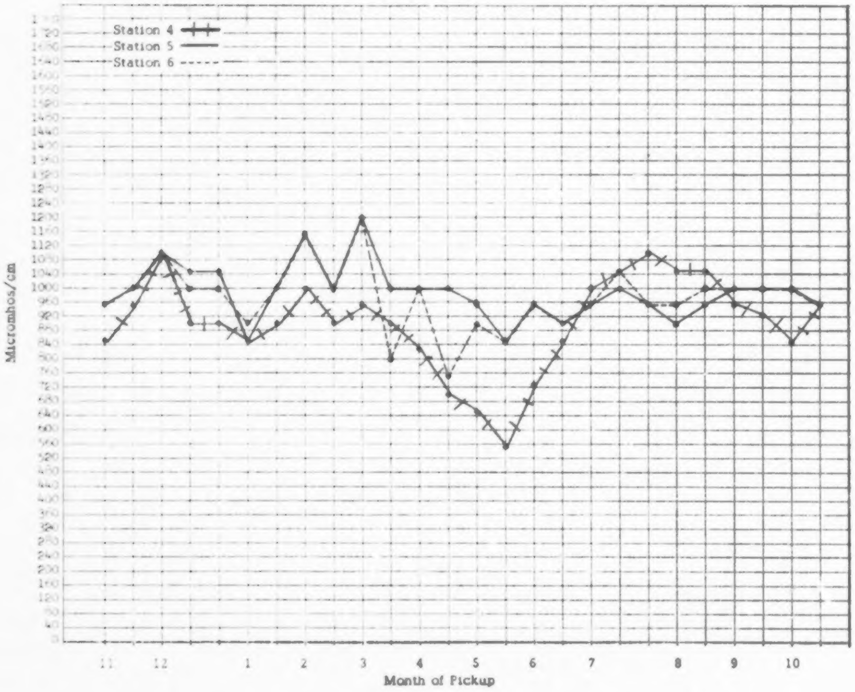

Figure 46. Midway Hatchery, Specific Conductance. Stations 4, 5 and 6.

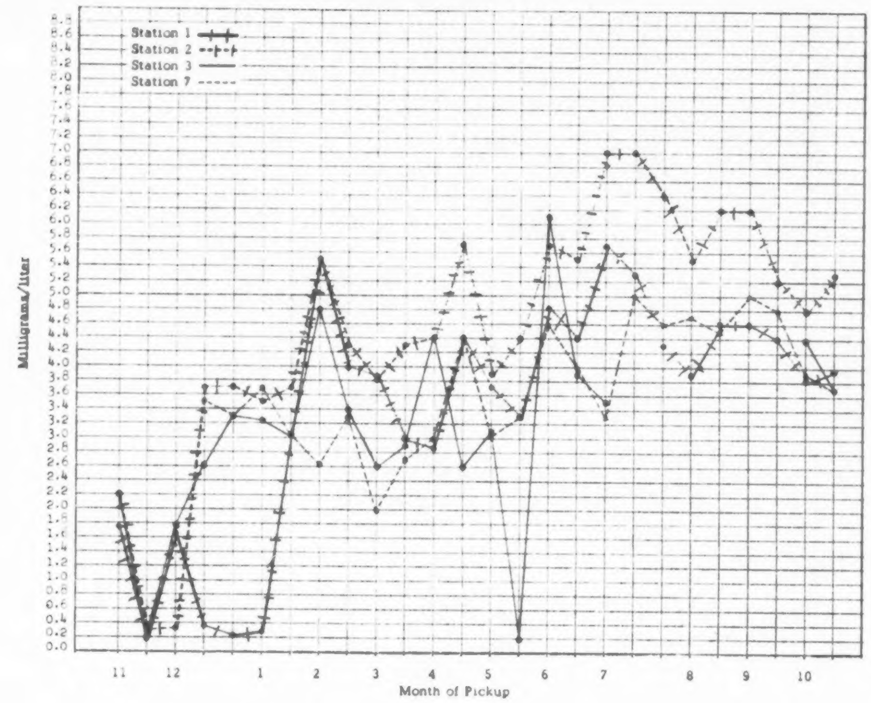

Figure 47. Midway Hatchery, Nitrate, Stations 1, 2, 3 and 7.

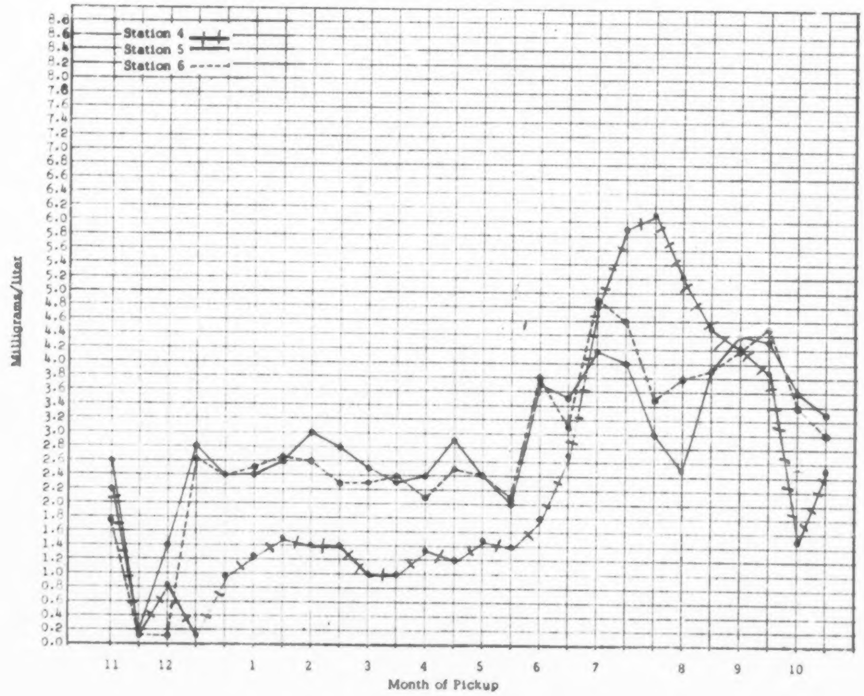

Figure 48. Midway Hatchery, Nitrate, Stations 4, 5 and 6.

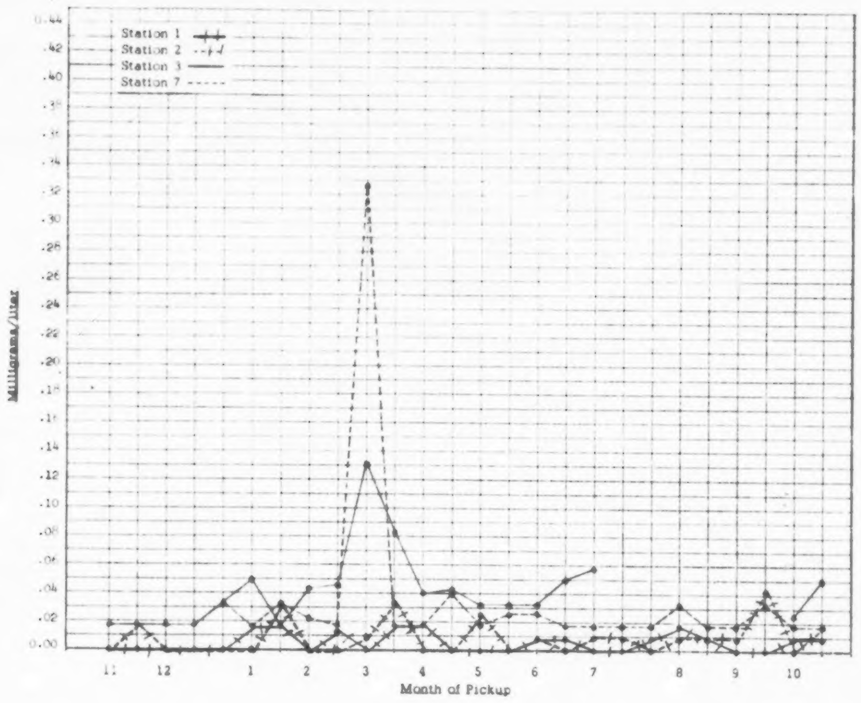

Figure 49. Midway Hatchery, Nitrite, Stations 1, 2, 3 and 7.

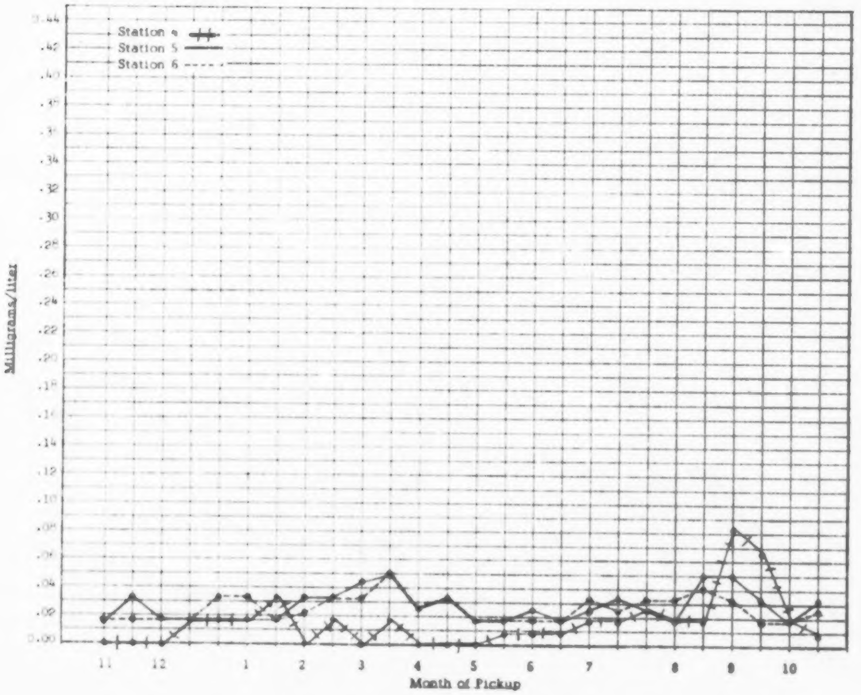

Figure 50. Midway Hatchery, Nitrite, Stations 4, 5 and 6.

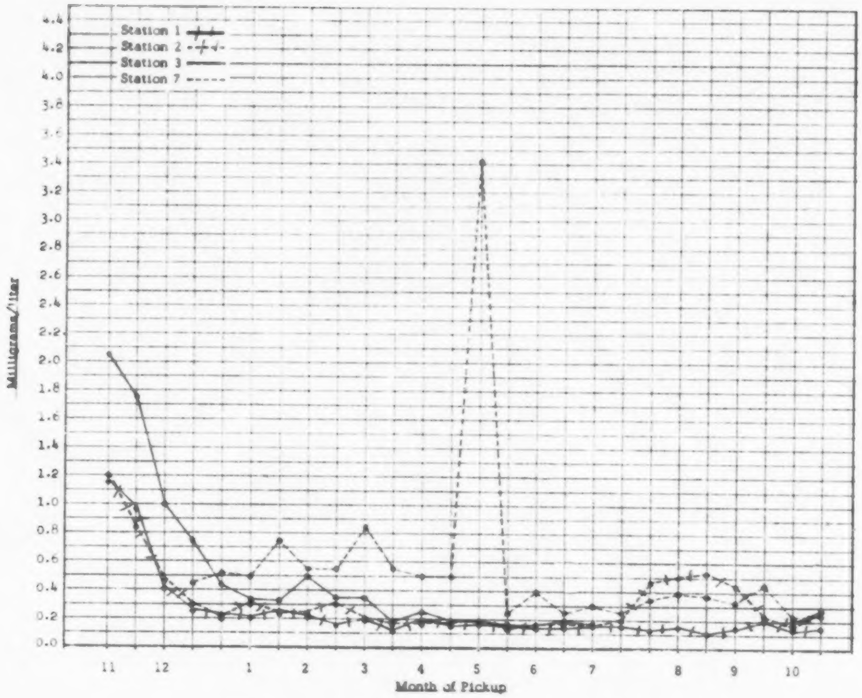

Figure 51. Midway Hatchery, Ammonia. Stations 1, 2, 3 and 7.

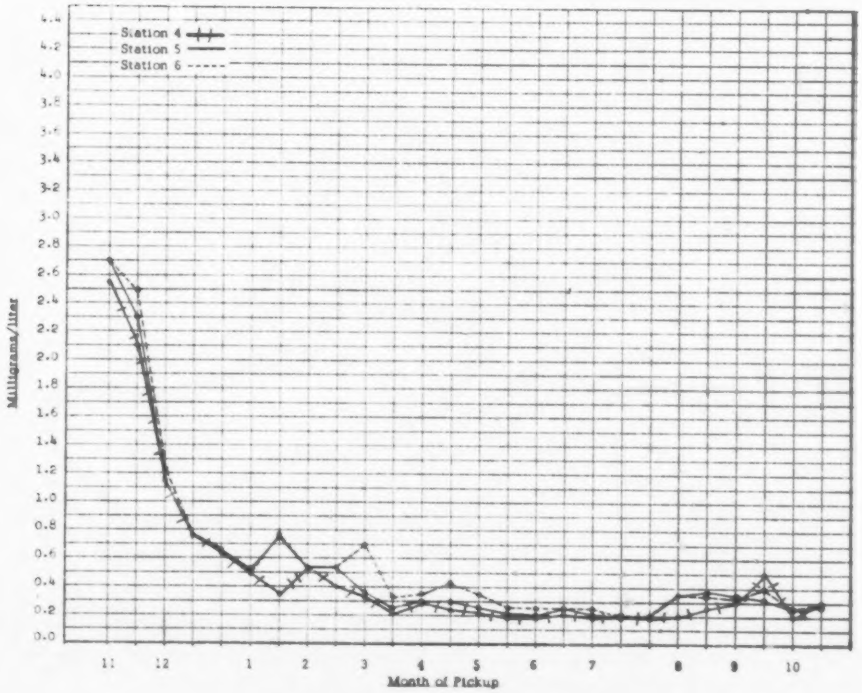

Figure 52. Midway Hatchery, Ammonia. Stations 4, 5 and 6.

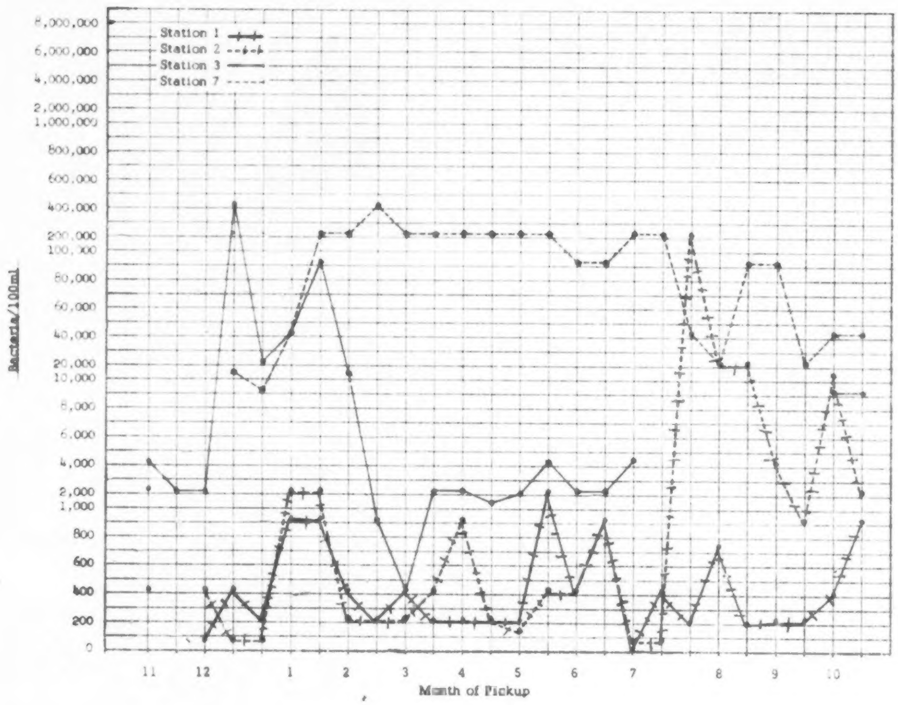

Figure 53. Midway Hatchery, M.P.Ñ. Coliform. Stations 1, 2, 3 and 7.

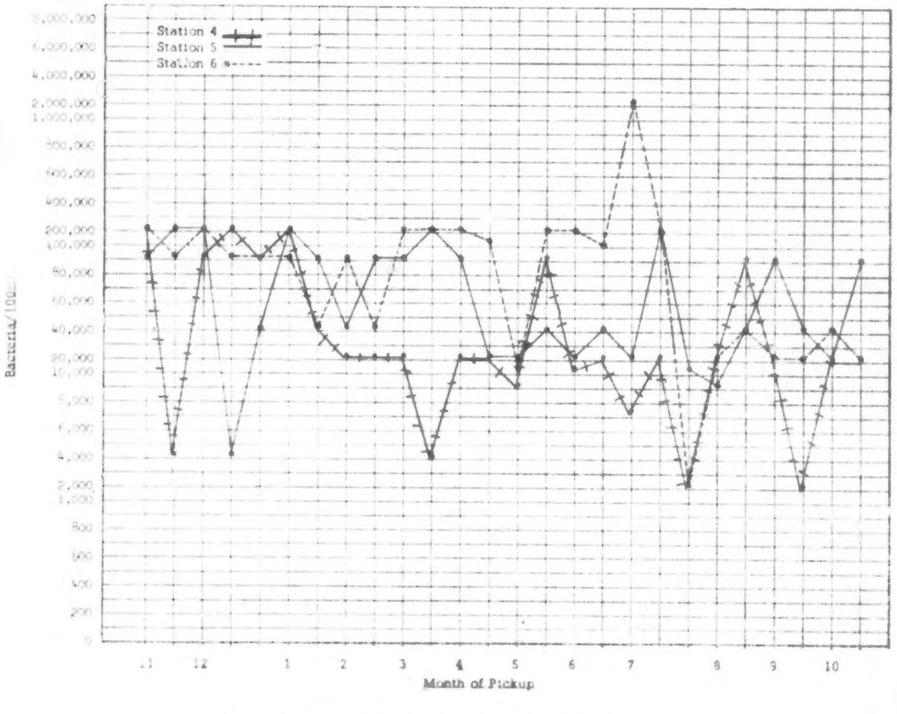

Figure 54. Midway Hatchery, M.P.N. Coliform. Stations 4, 5 and 6.

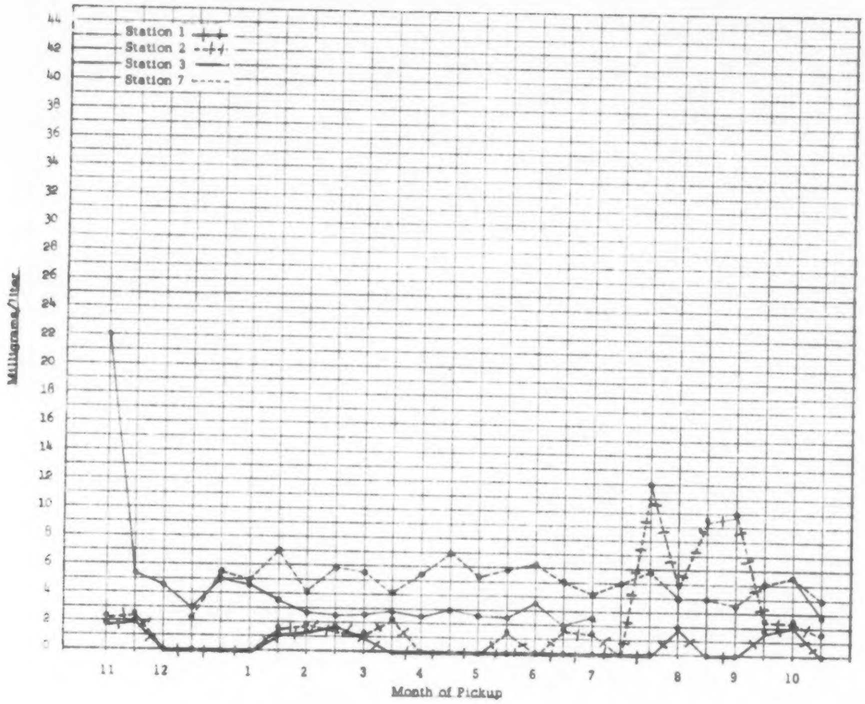

Figure 55. Midway Hatchery, Biochemical Oxygen Demand. Stations 1, 2, 3 and 7.

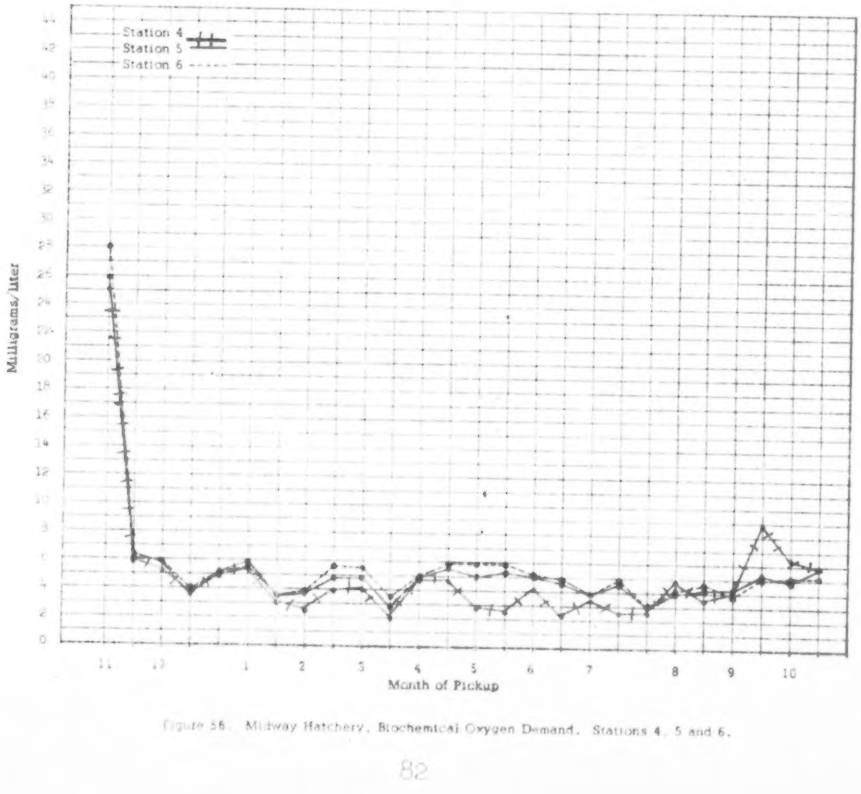

Figure 56. Midway Hatchery, Biochemical Oxygen Demand. Stations 4, 5 and 6.

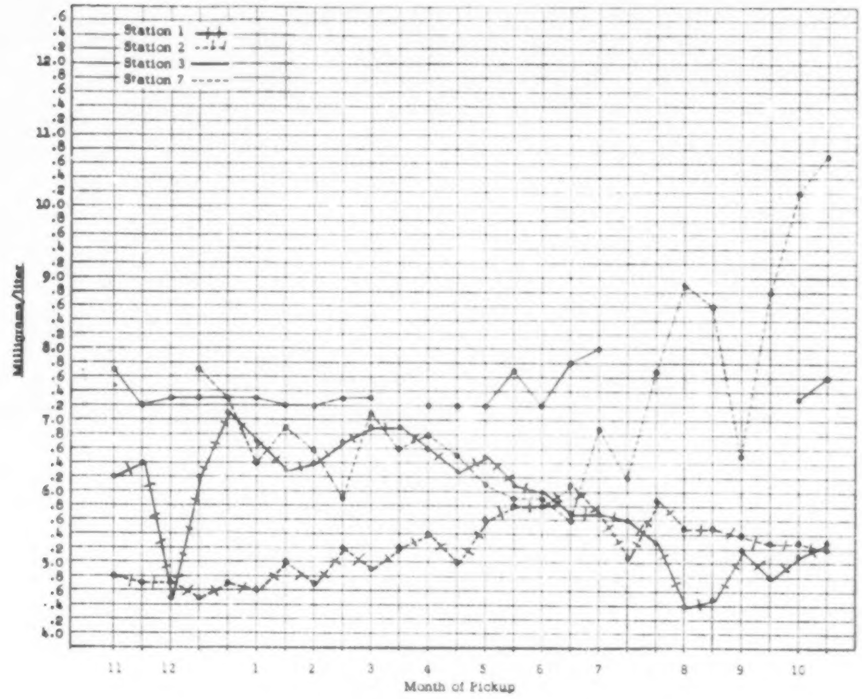

Figure 57. Midway Hatchery, Dissolved Oxygen. Stations 1, 2, 3 and 7.

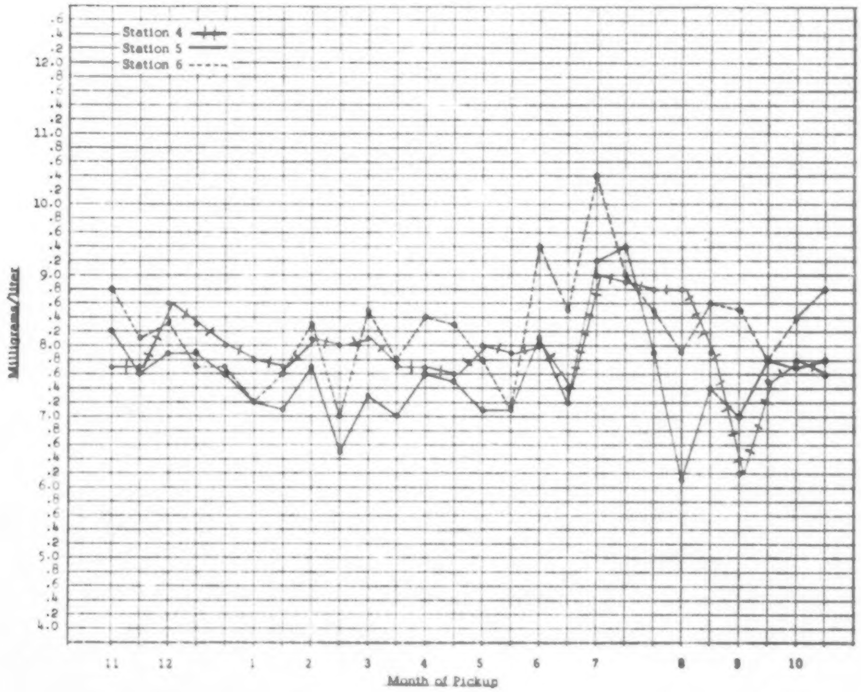

Figure 58. Midway Hatchery, Dissolved Oxygen. Stations 4, 5 and 6.

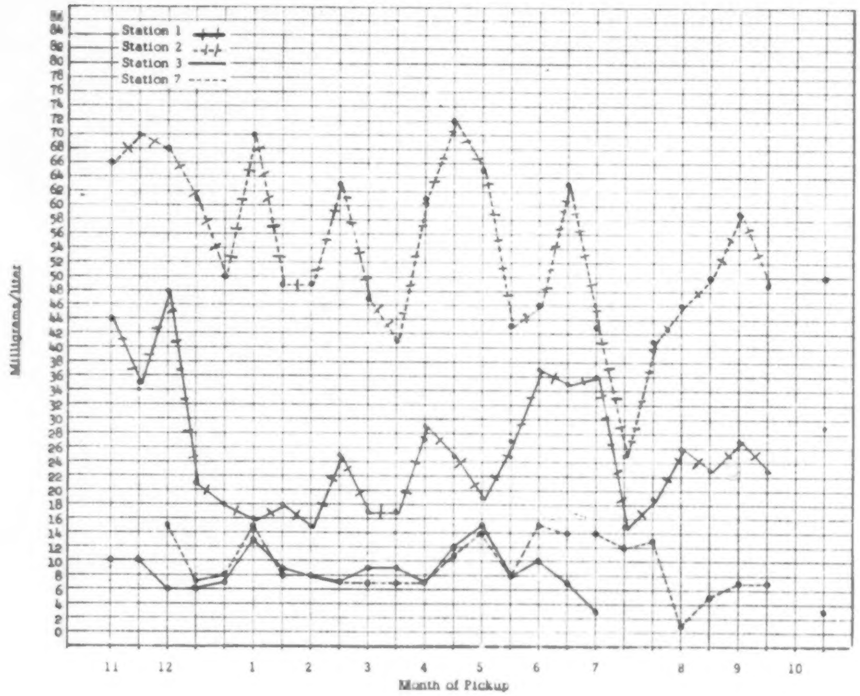

Figure 59. Midway Hatchery. Carbon Dioxide. Stations 1, 2, 3 and 7.

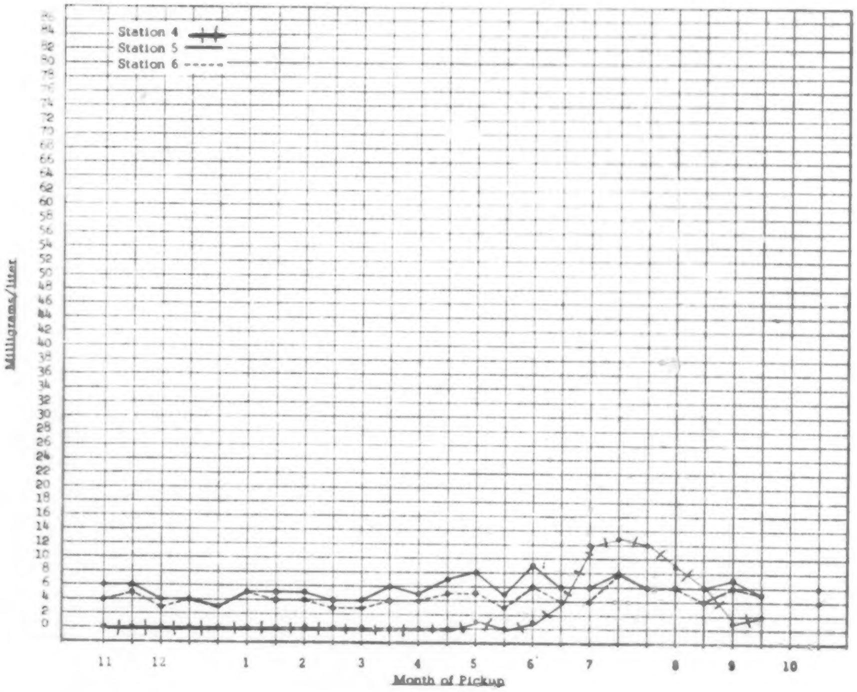

Figure 60. Midway Hatchery. Carbon Dioxide. Stations 4, 5 and 6.

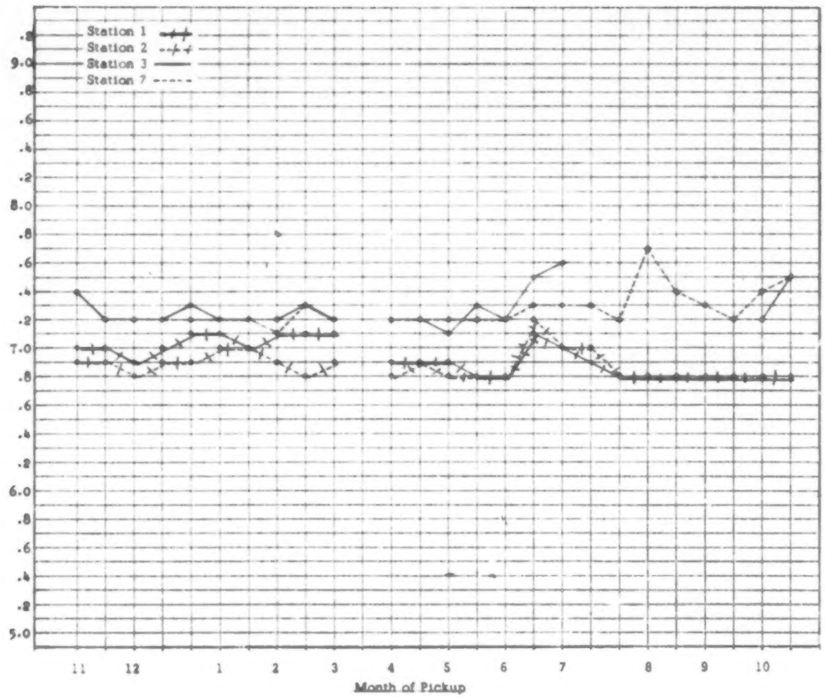

Figure 61. Midway Hatchery, Hydrogen Ion Concentration. Stations 1, 2, 3 and 7.

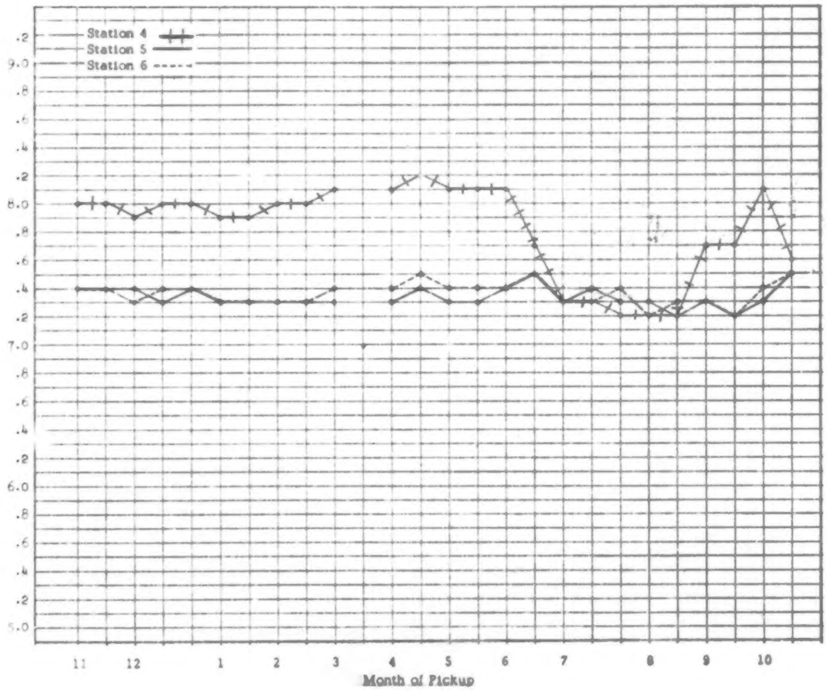

Figure 62. Midway Hatchery, Hydrogen Ion Concentration. Stations 4, 5 and 6.

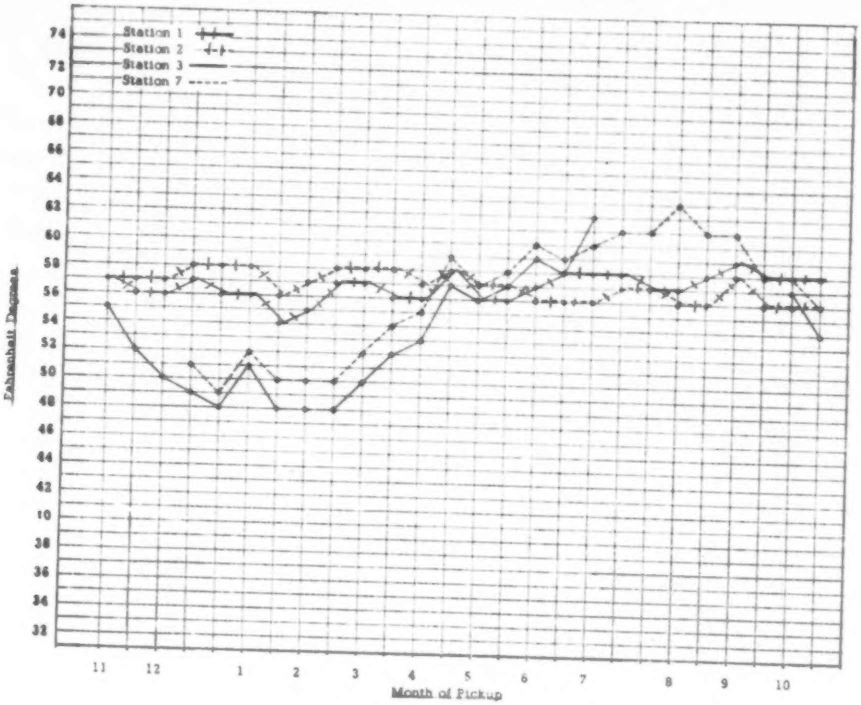

Figure 63. Midway Hatchery, Temperature, Stations 1, 2, 3 and 7.

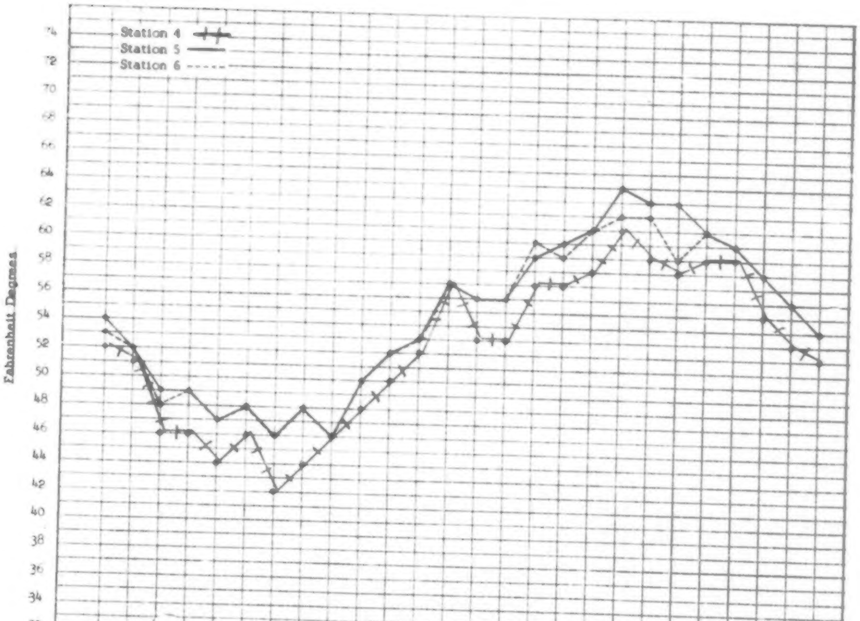

Figure 64. Midway Hatchery, Temperature, Stations 4, 5 and 6.

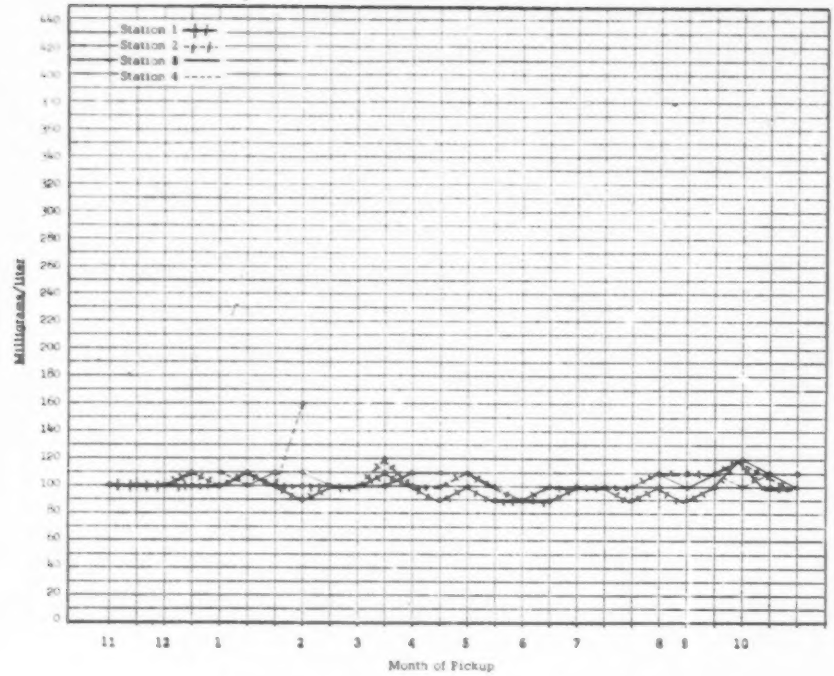

Figure 65. Loa Hatchery. M.O. Alkalinity. Stations 1, 2, 3 and 4.

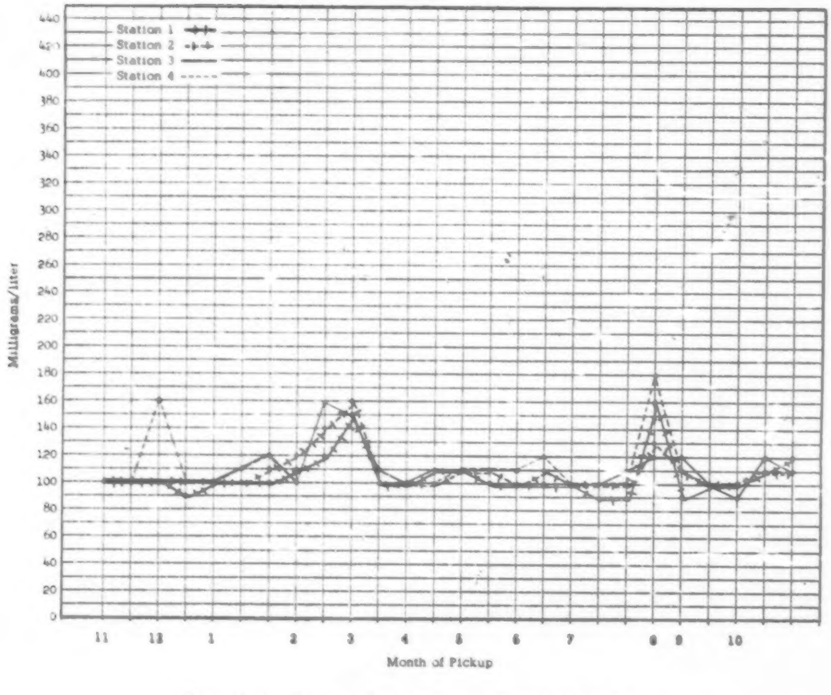

Figure 66. Loa Hatchery. Total Hardness. Stations 1, 2, 3 and 4.

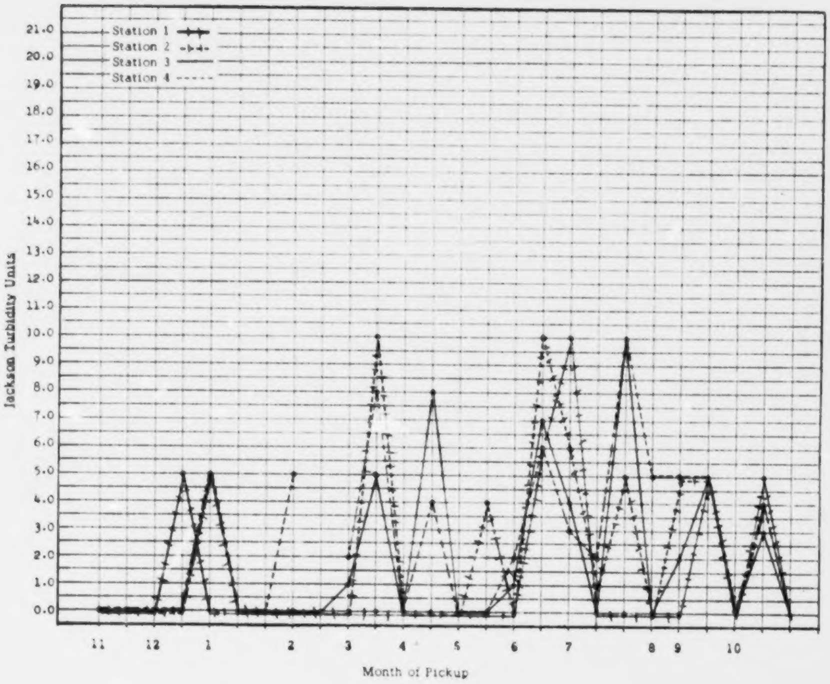

Figure 67. Loa Hatchery. Turbidity. Stations 1, 2, 3 and 4.

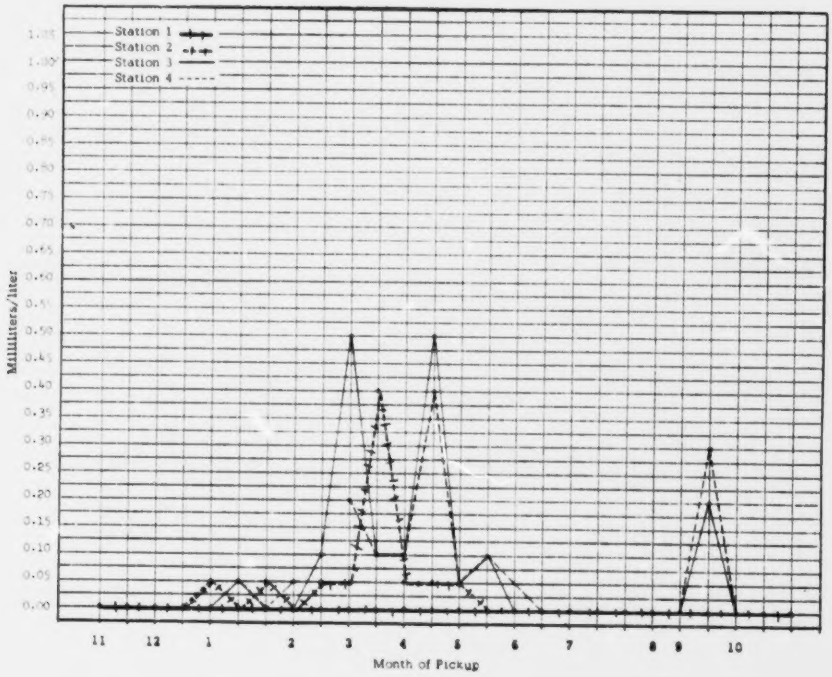

Figure 68. Loa Hatchery. Settleable Solids. Stations 1, 2, 3 and 4.

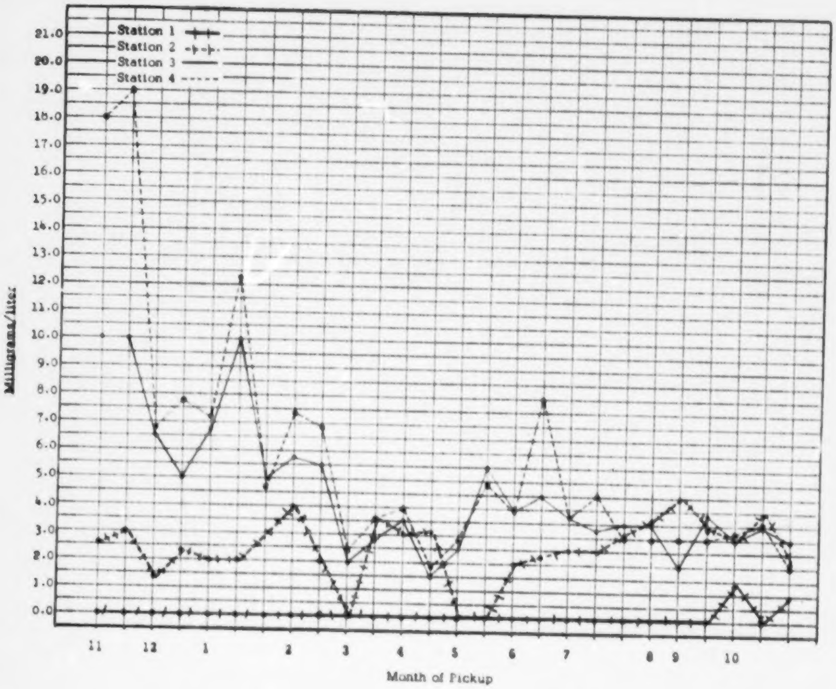

Figure 69. Loa Hatchery. Suspended Solids. Stations 1, 2, 3 and 4.

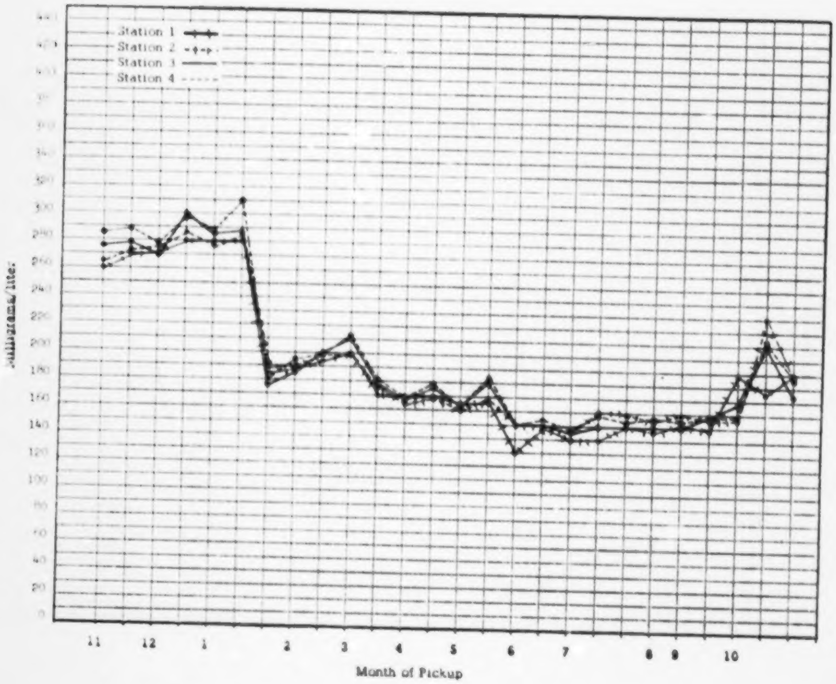

Figure 70. Loa Hatchery. Total Dissolved Solids. Stations 1, 2, 3 and 4.

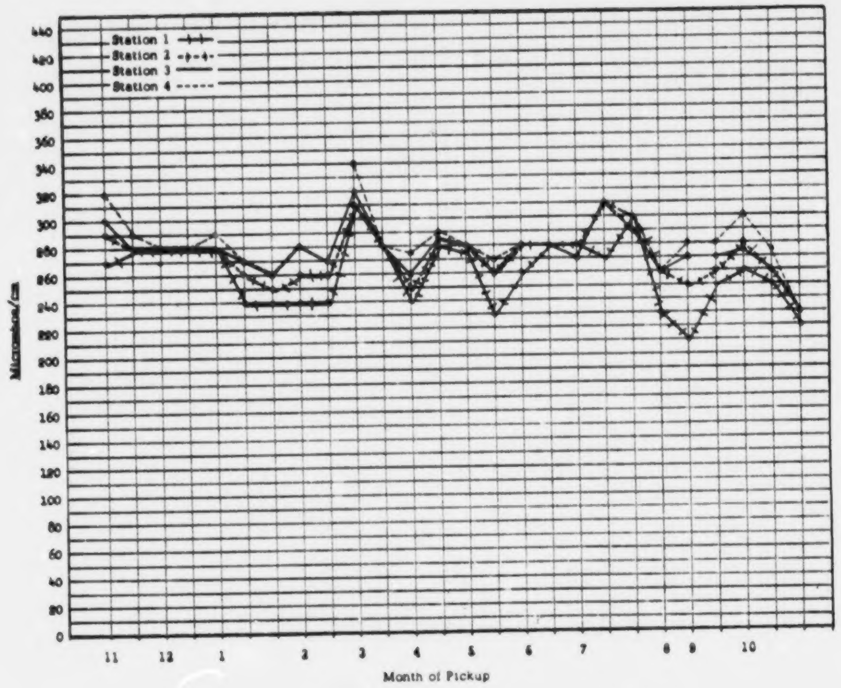

Figure 71. Los Hatchery. Specific Conductance. Stations 1, 2, 3 and 4.

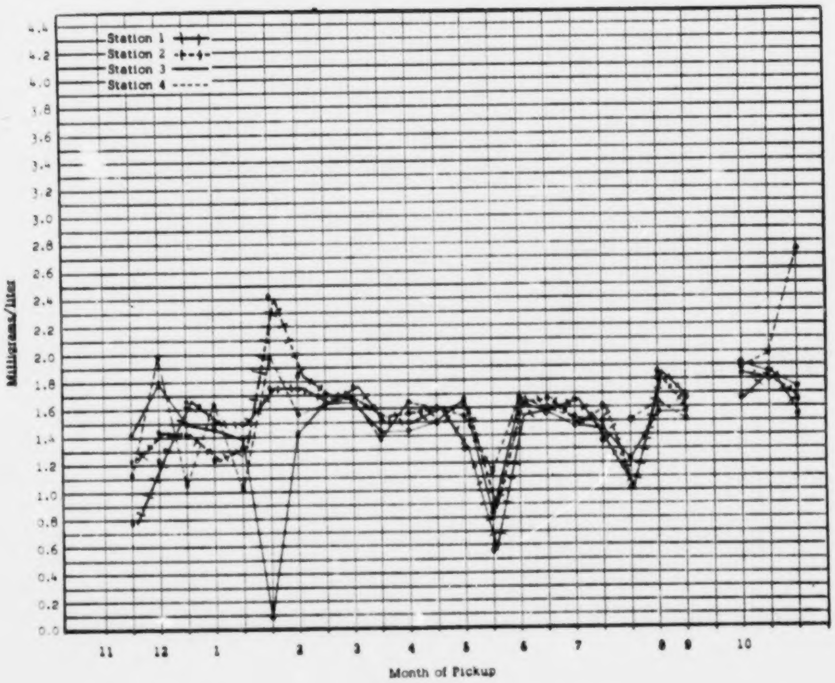

Figure 72. Los Hatchery. Nitrate. Stations 1, 2, 3 and 4.

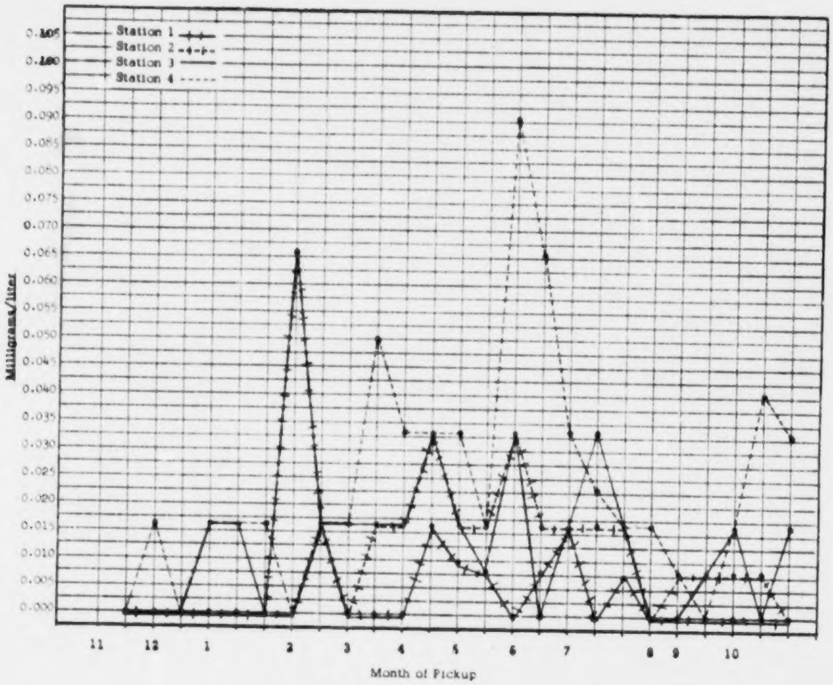

Figure 73. Loa Hatchery, Nitrite, Stations 1, 2, 3 and 4.

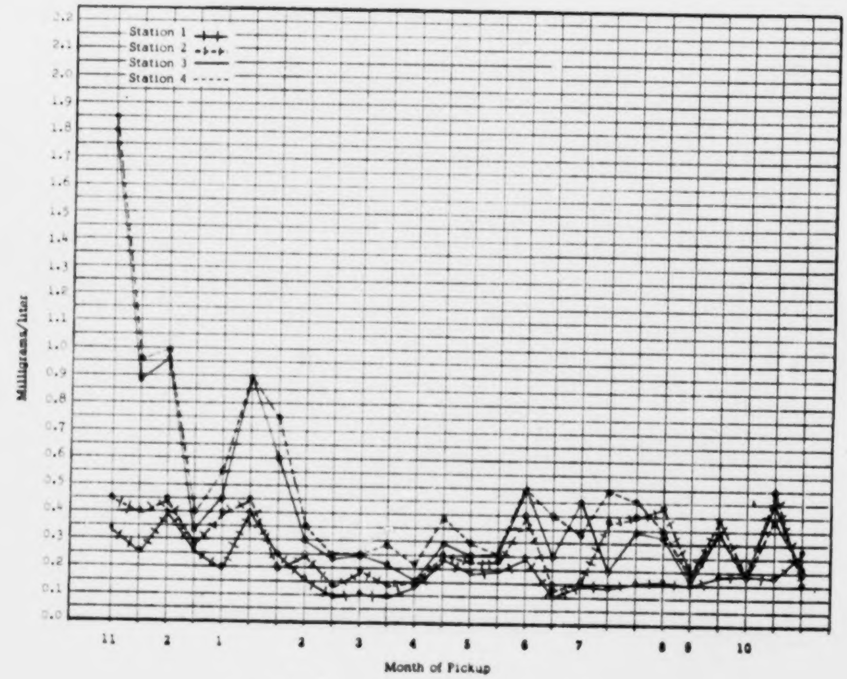

Figure 74. Loa Hatchery, Ammonia, Stations 1, 2, 3 and 4.

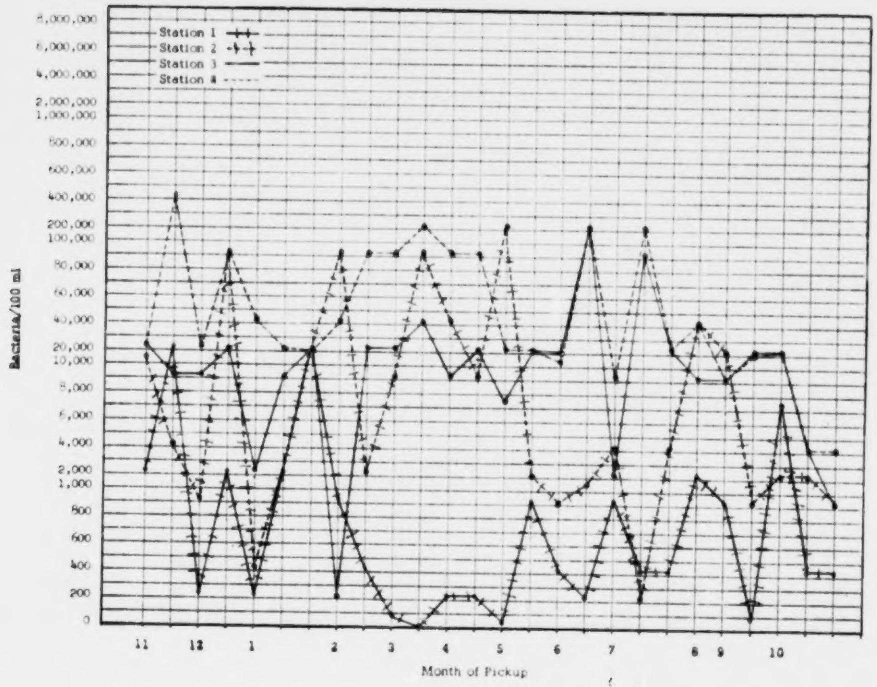

Figure 75. Loa Hatchery. M.P.N. Coliform. Stations 1, 2, 3 and 4.

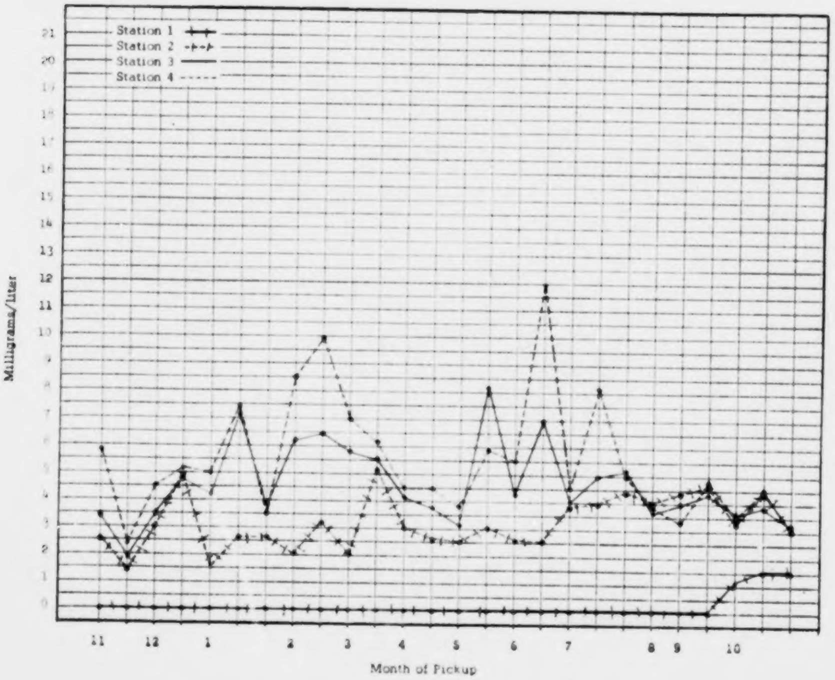

Figure 76. Loa Hatchery. Biochemical Oxygen Demand. Stations 1, 2, 3 and 4.

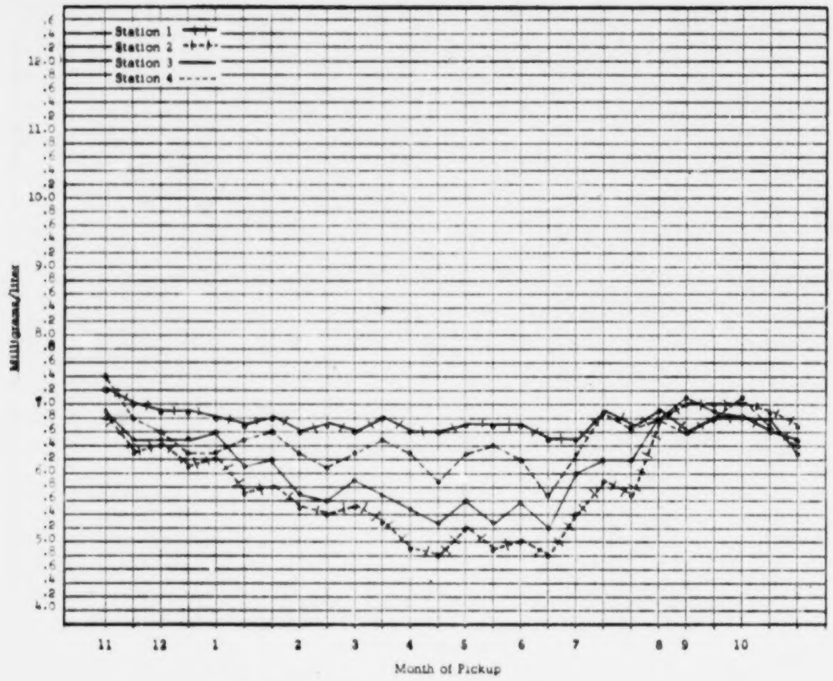

Figure 77. Loa Hatchery. Dissolved Oxygen. Stations 1, 2, 3 and 4.

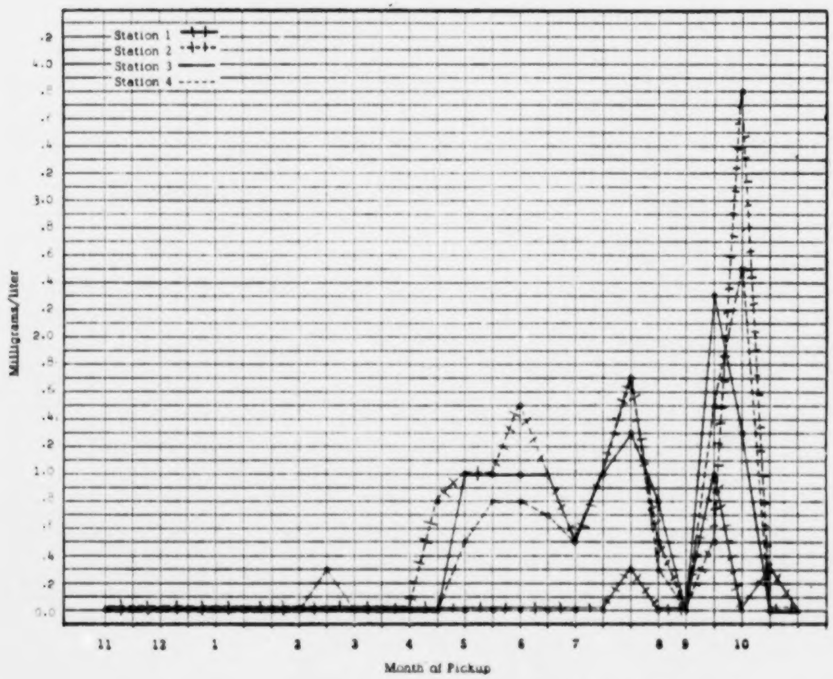

Figure 78. Loa Hatchery. Carbon Dioxide. Stations 1, 2, 3 and 4.

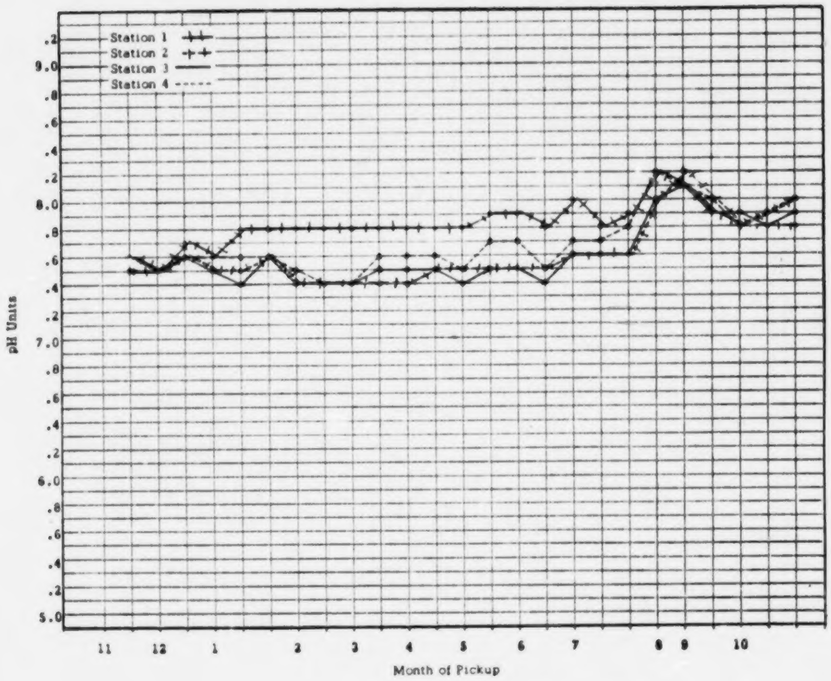

Figure 79. Loa Hatchery. Hydrogen Ion Concentration. Stations 1, 2, 3 and 4.

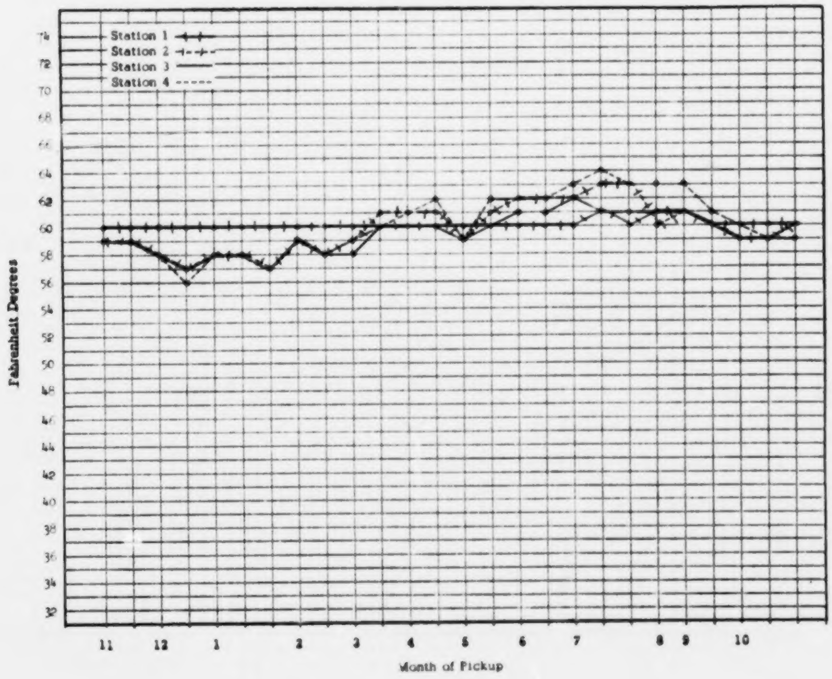

Figure 80. Loa Hatchery. Temperature. Stations 1, 2, 3 and 4.

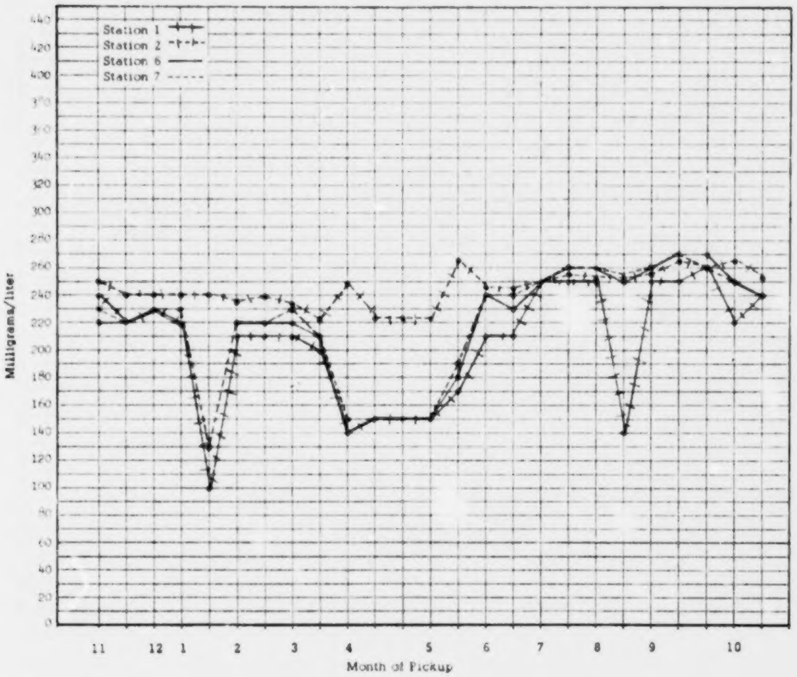

Figure 81. White's Trout Farm. M.O. Alkalinity. Stations 1, 2, 6 and 7.

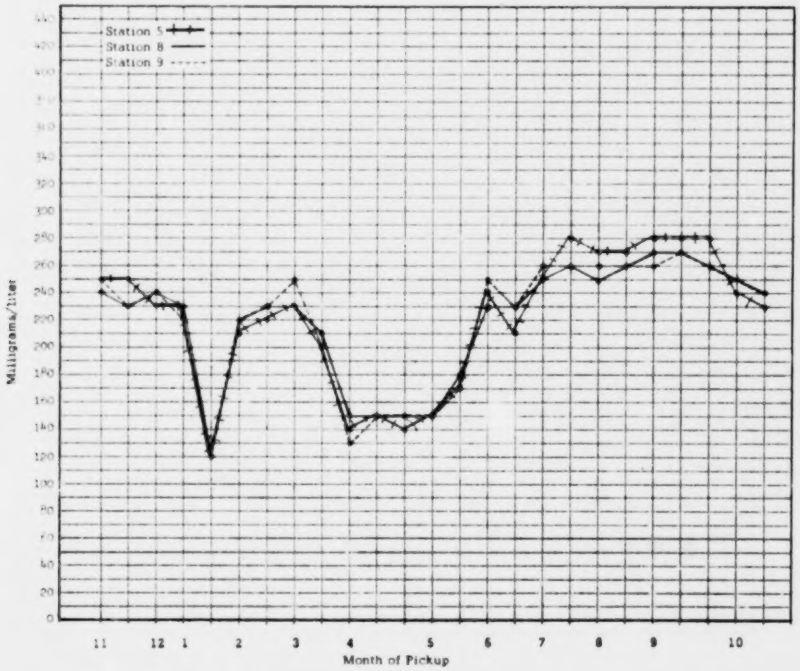

Figure 82. White's Trout Farm. M.O. Alkalinity. Stations 5, 8 and 9.

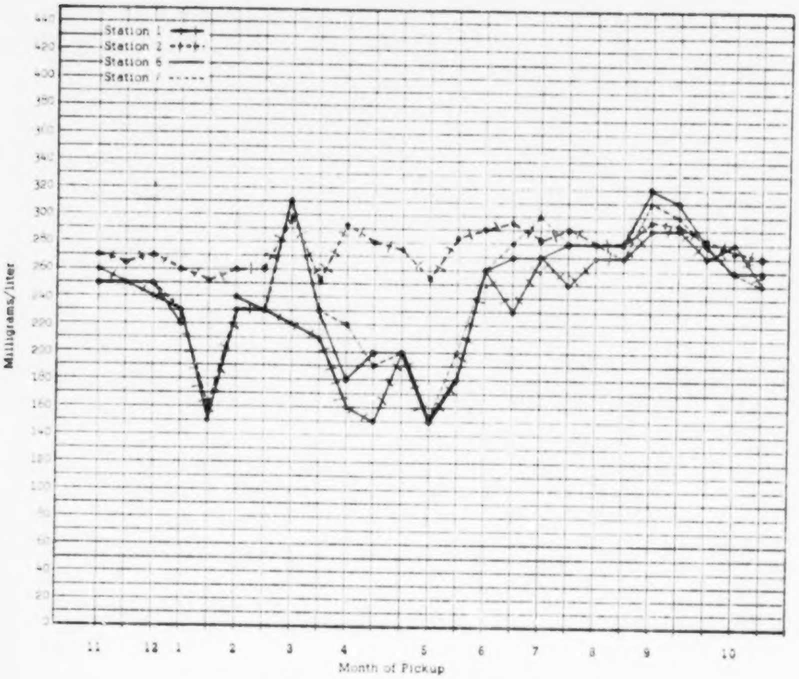

Figure 83. White's Trout Farm. Total Hardness. Stations 1, 2, 6 and 7.

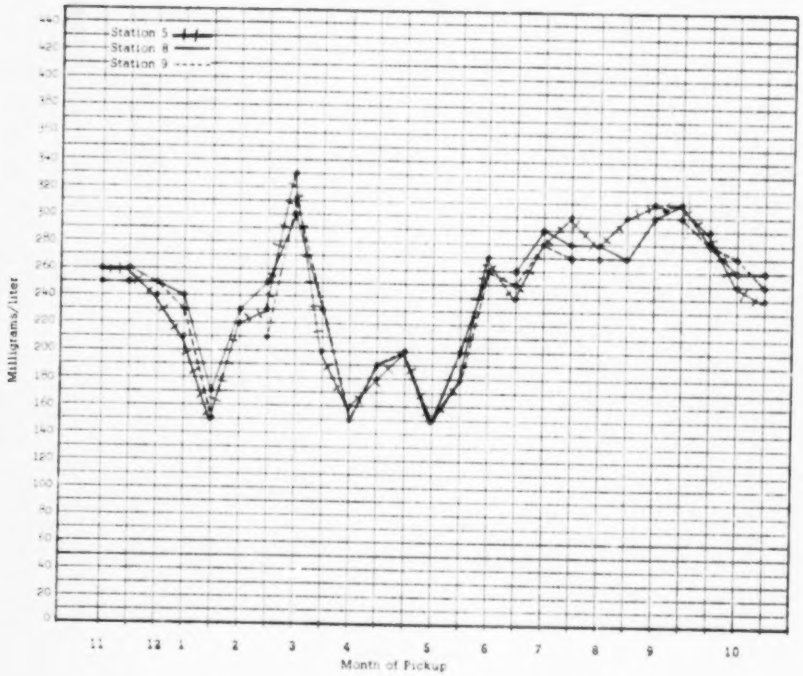

Figure 84. White's Trout Farm. Total Hardness. Stations 5, 8 and 9.

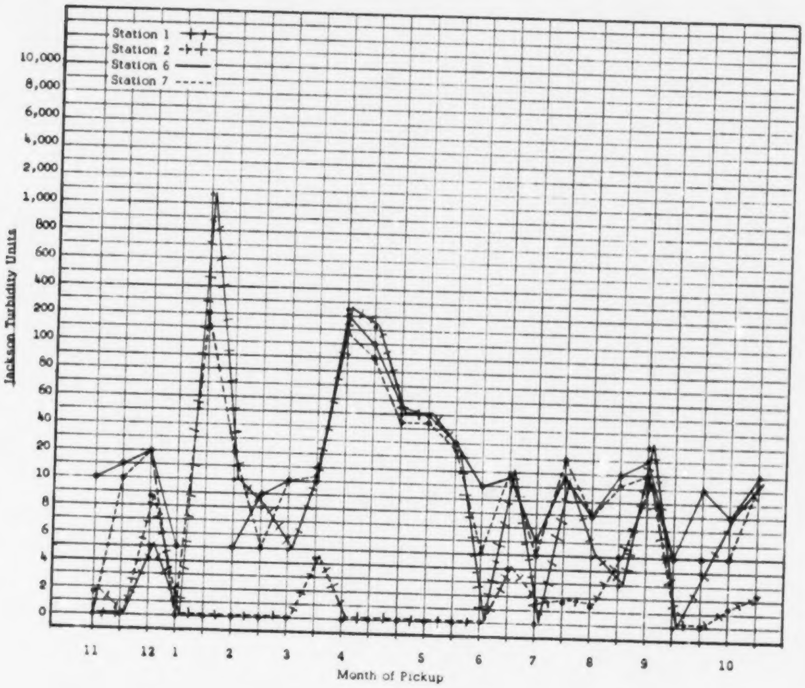

Figure 85. White's Trout Farm. Turbidity. Stations 1, 2, 6 and 7.

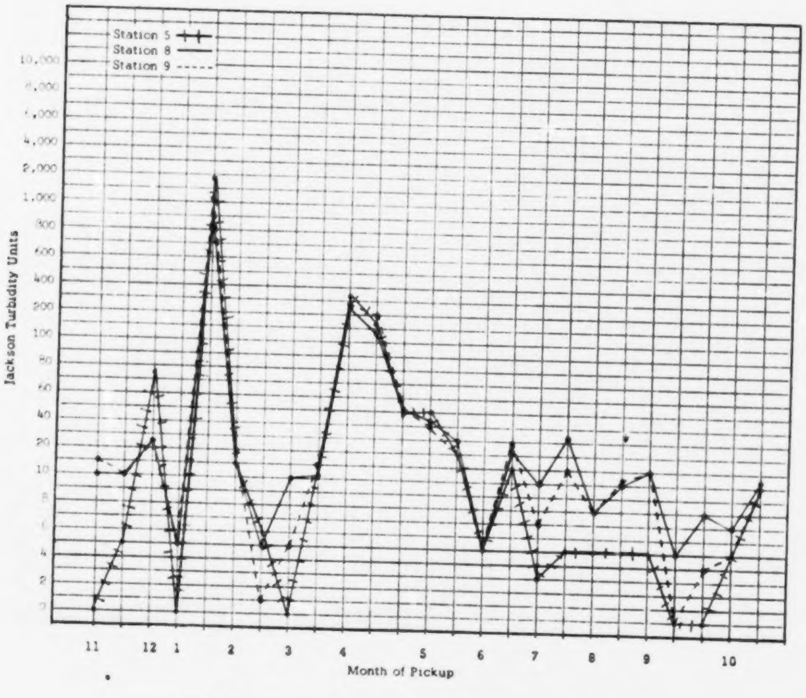

Figure 86. White's Trout Farm. Turbidity. Stations 5, 8 and 9.

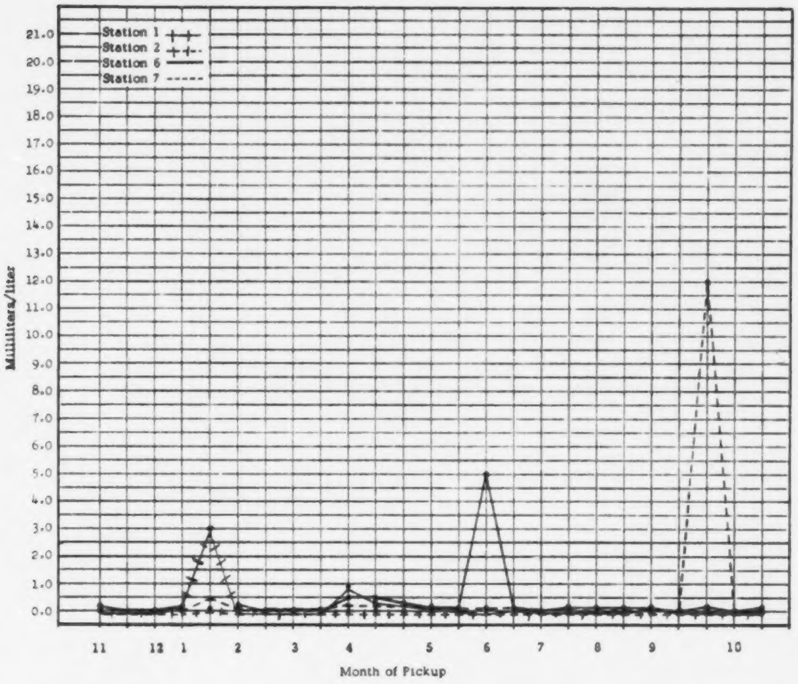

Figure 87. White's Trout Farm. Settleable Solids. Stations 1, 2, 6 and 7.

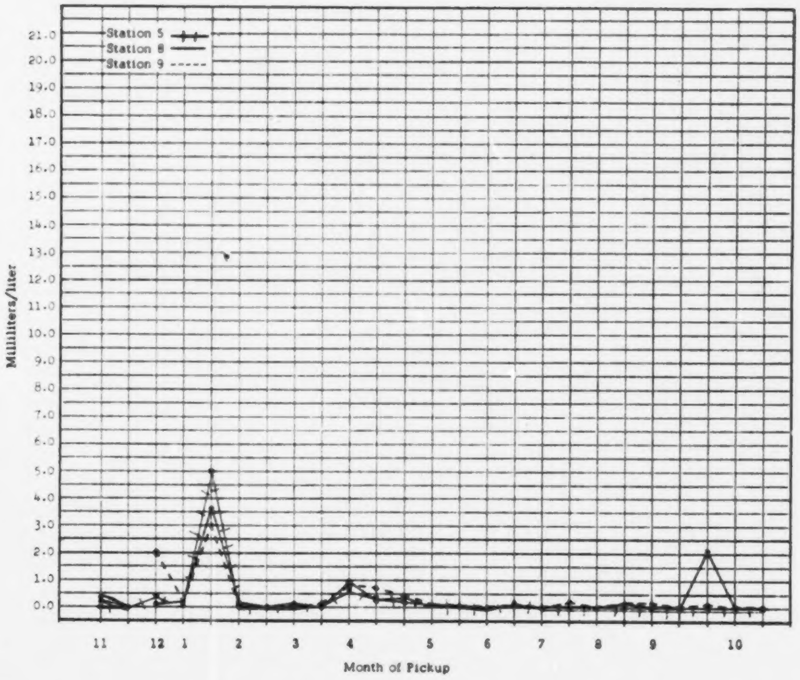

Figure 88. White's Trout Farm. Settleable Solids. Stations 5, 8 and 9.

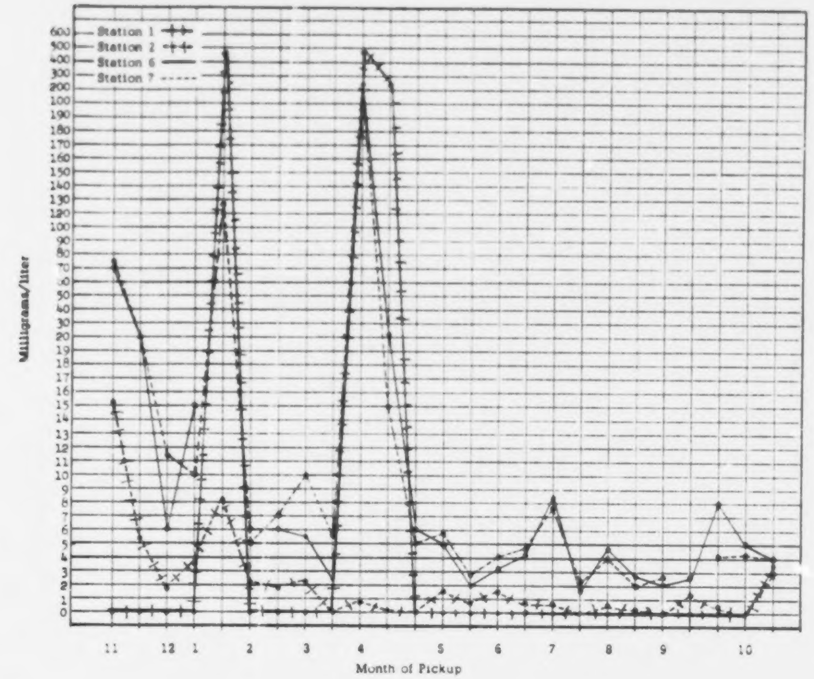

Figure 89. White's Trout Farm. Suspended Solids. Stations 1, 2, 6 and 7.

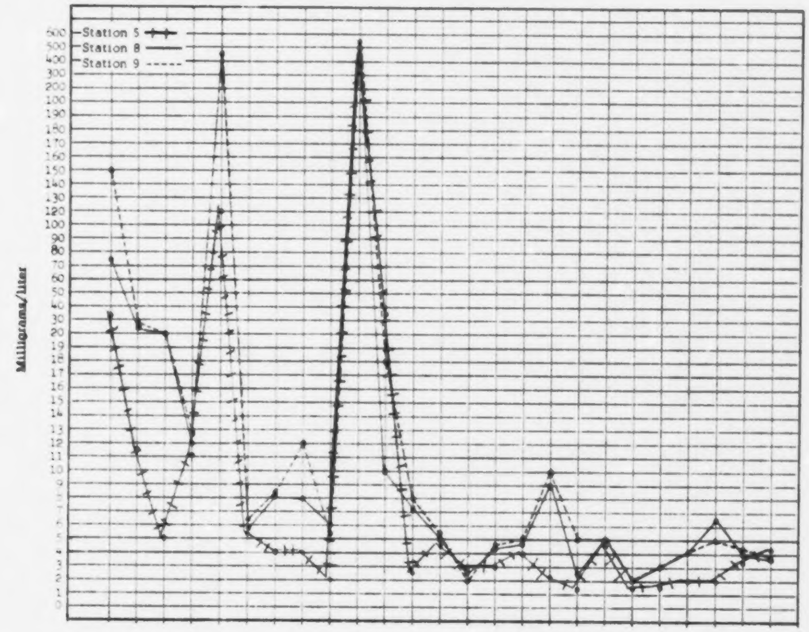

Figure 90. White's Trout Farm. Suspended Solids. Stations 5, 8 and 9.

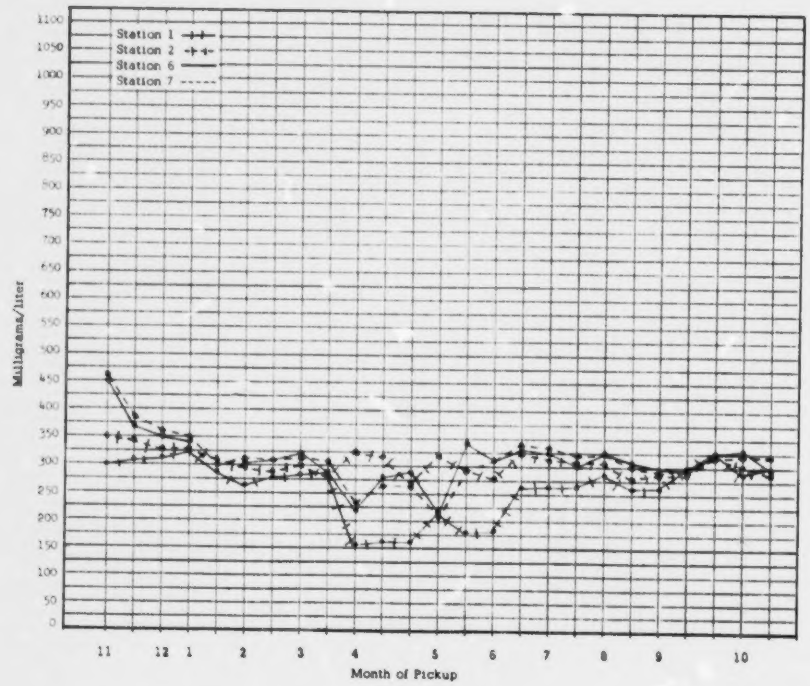

Figure 91. White's Trout Farm. Total Dissolved Solids. Stations 1, 2, 6 and 7.

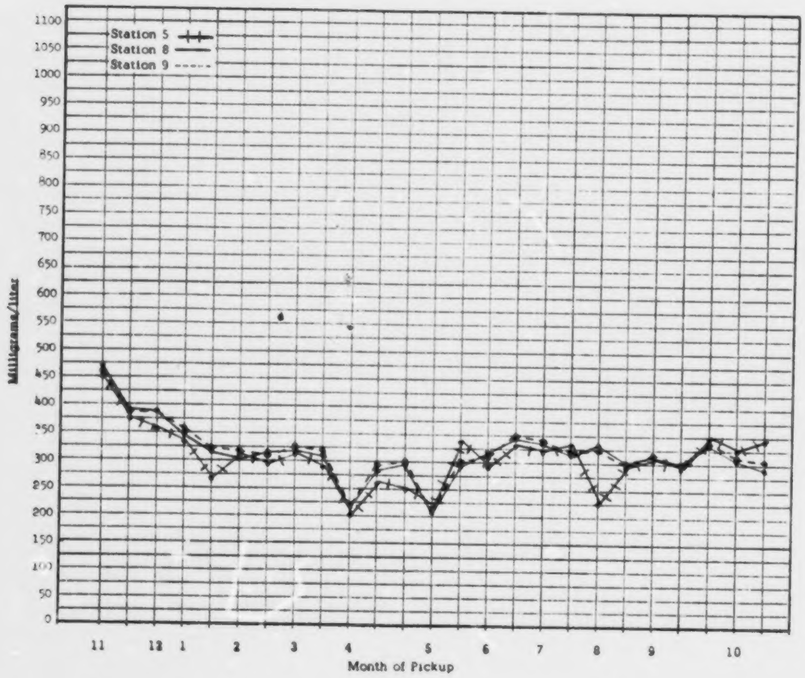

Figure 92. White's Trout Farm. Total Dissolved Solids. Stations 5, 8 and 9.

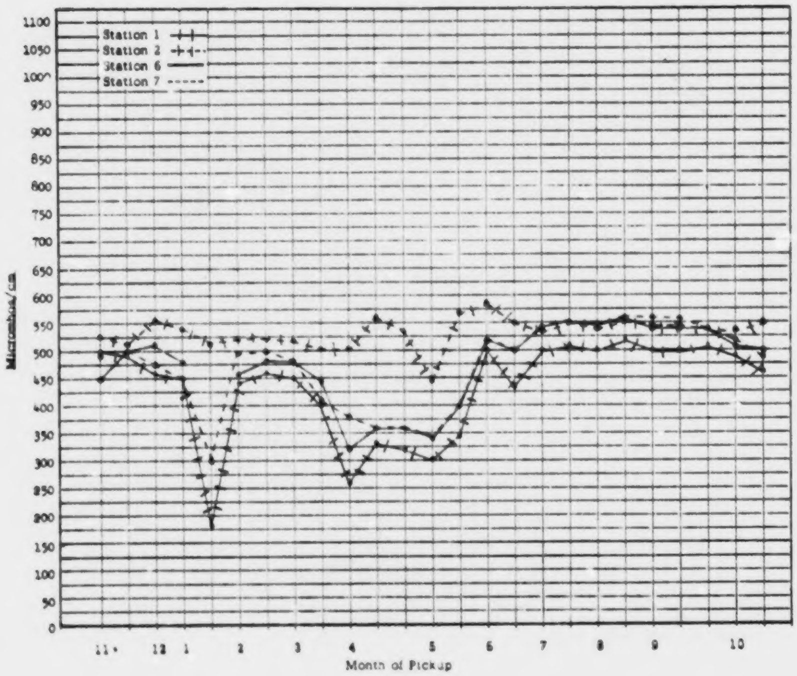

Figure 93. White's Trout Farm. Specific Conductance. Stations 1, 2, 6 and 7.

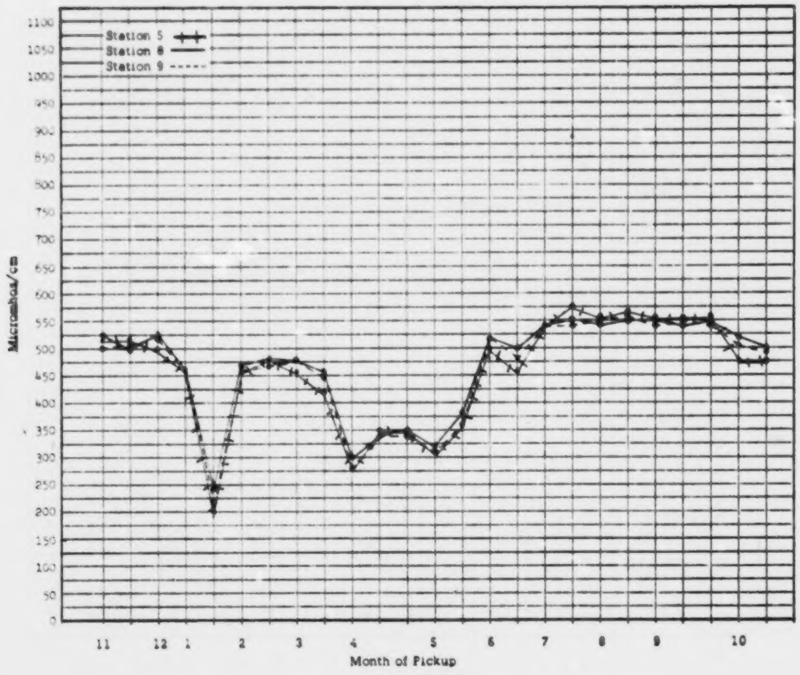

Figure 94. White's Trout Farm. Specific Conductance. Stations 5, 8 and 9.

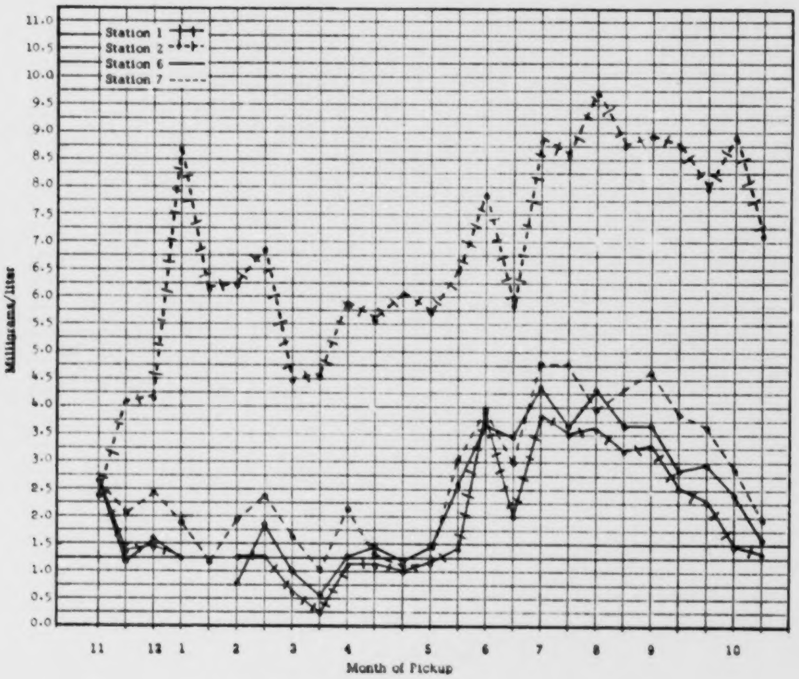

Figure 95. White's Trout Farm, Nitrate, Stations 1, 2, 6 and 7.

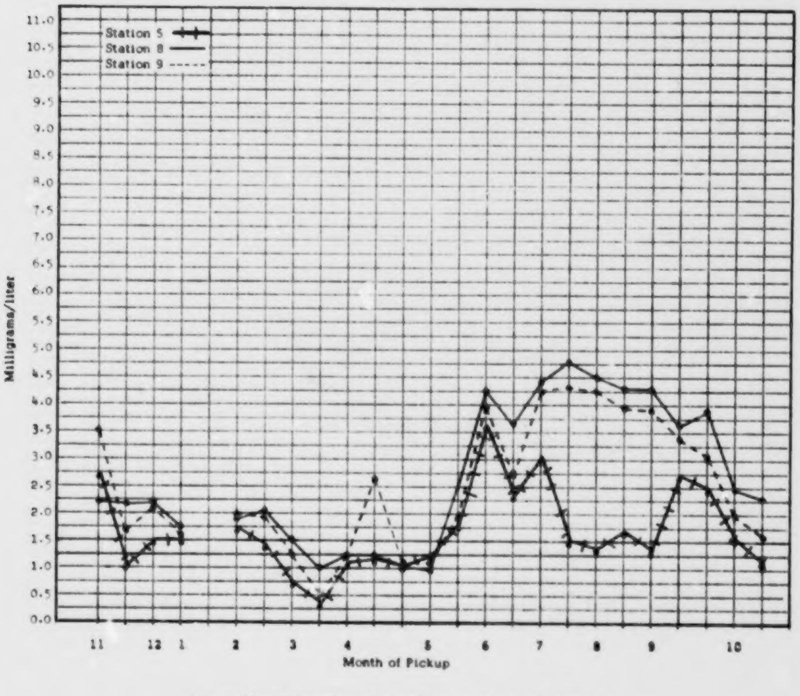

Figure 96. White's Trout Farm, Nitrate, Stations 5, 8 and 9.

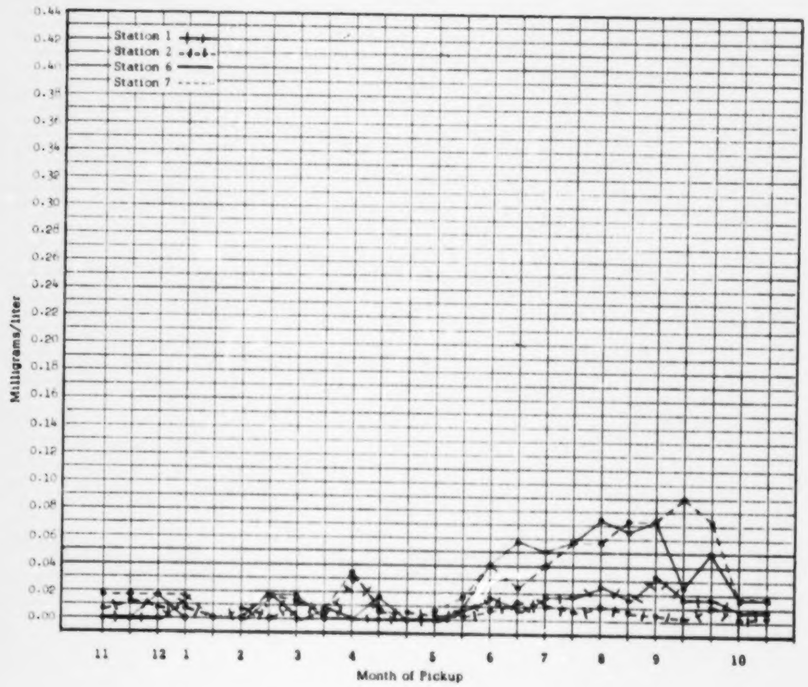

Figure 97. White's Trout Farm, Nitrite. Stations 1, 2, 6 and 7.

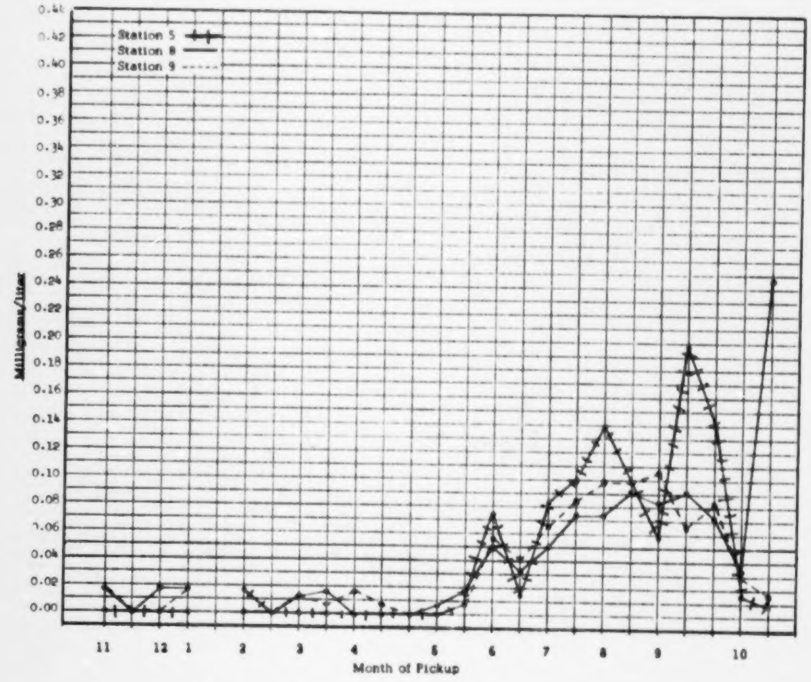

Figure 98. White's Trout Farm, Nitrite, Stations 5, 8 and 9.

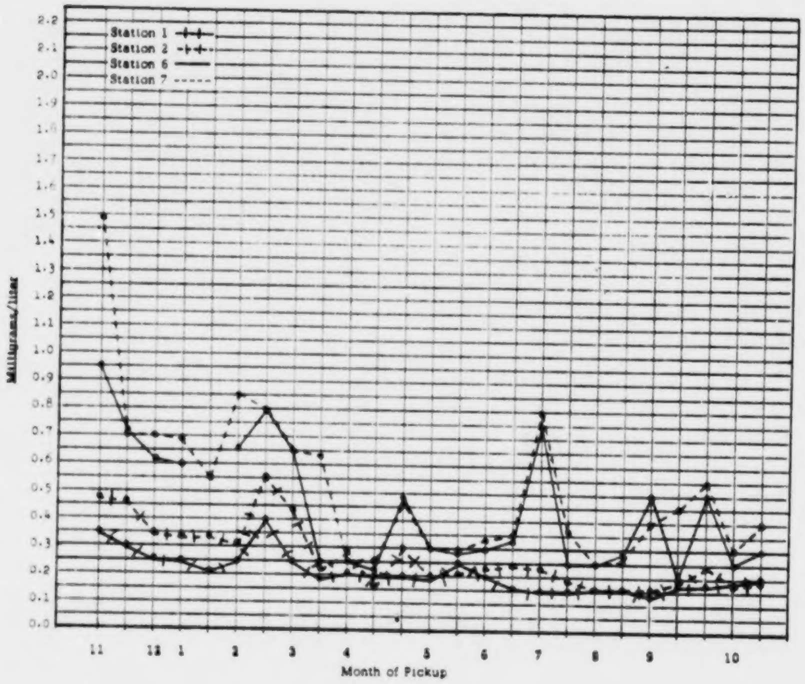

Figure 99. White's Trout Farm. Ammonia. Stations 1, 2, 6 and 7.

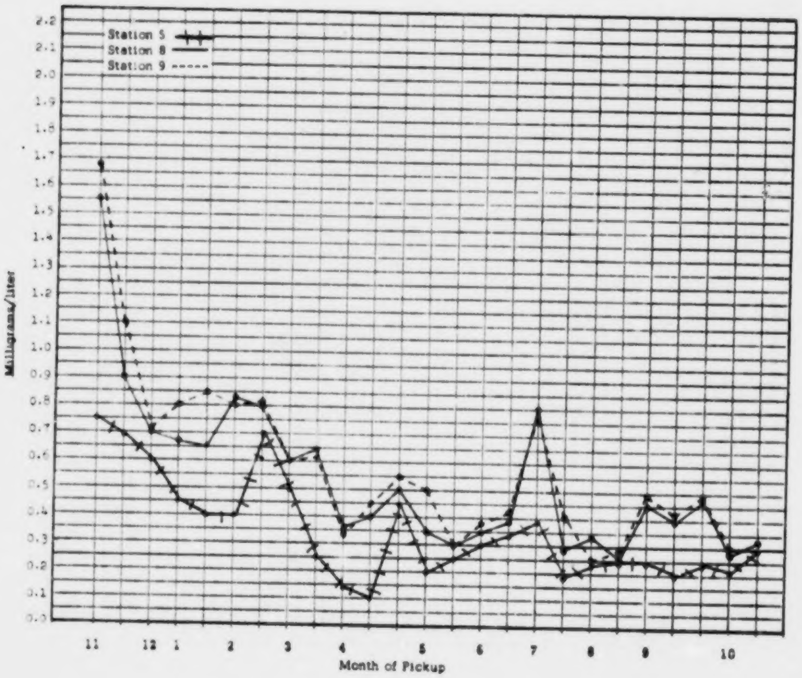

Figure 100. White's Trout Farm. Ammonia. Stations 5, 8 and 9.

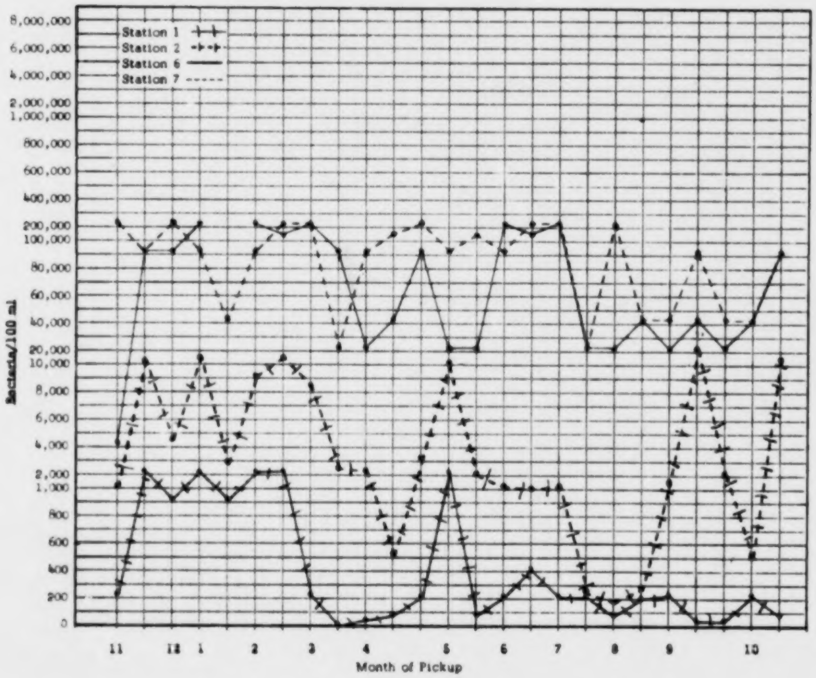

Figure 101. White's Trout Farm. M.P.N. Coliform. Stations 1, 2, 6 and 7.

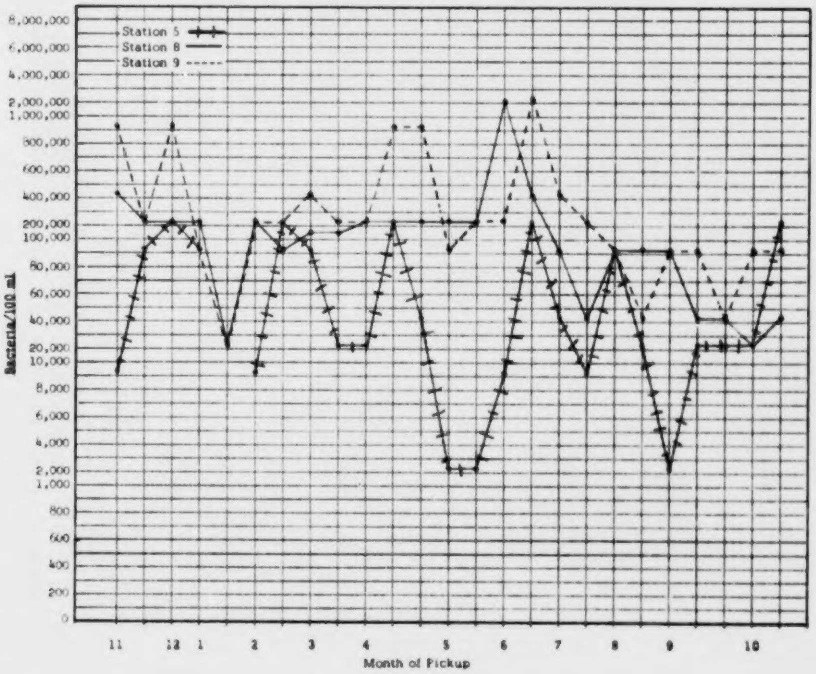

Figure 102. White's Trout Farm. M.P.N. Coliform. Stations 5, 8 and 9.

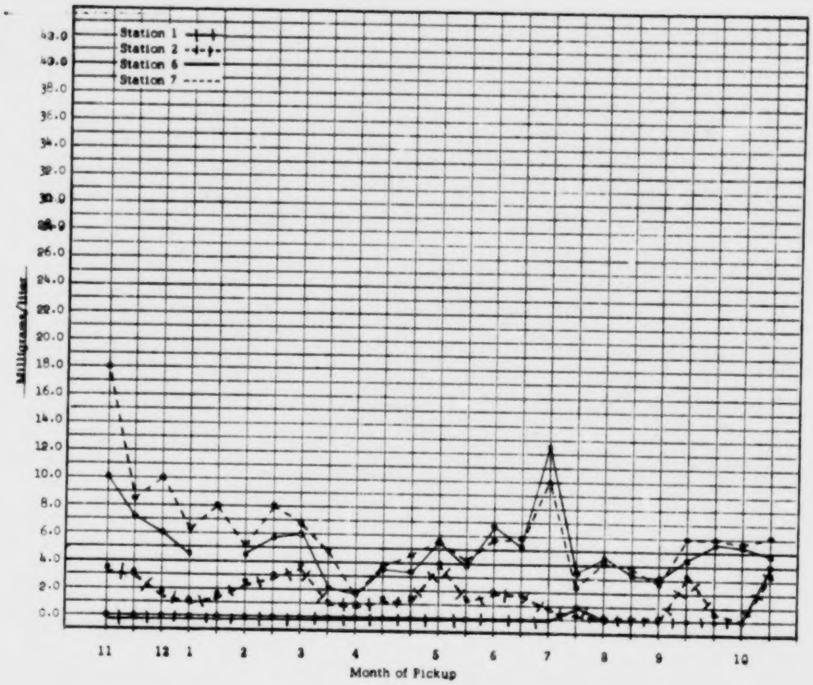

Figure 103. White's Trout Farm. Biochemical Oxygen Demand. Stations 1, 2, 6 and 7.

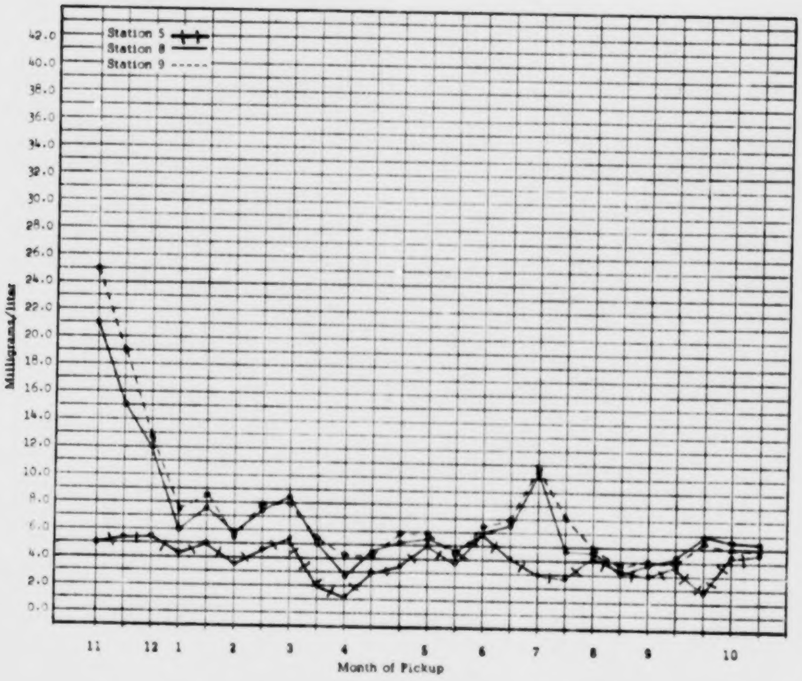

Figure 104. White's Trout Farm. Biochemical Oxygen Demand. Stations 5, 8 and 9.

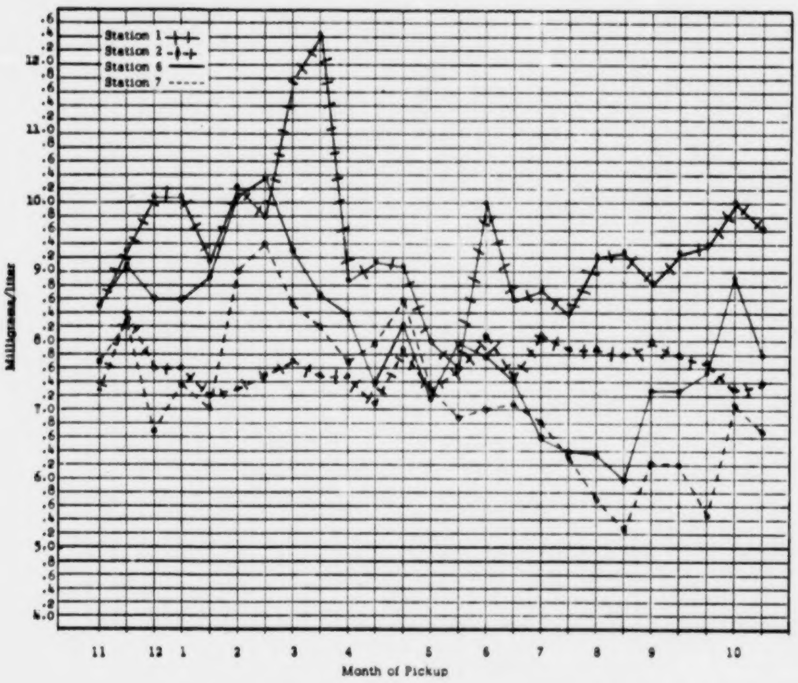

Figure 105. White's Trout Farm. Dissolved Oxygen. Stations 1, 2, 6 and 7.

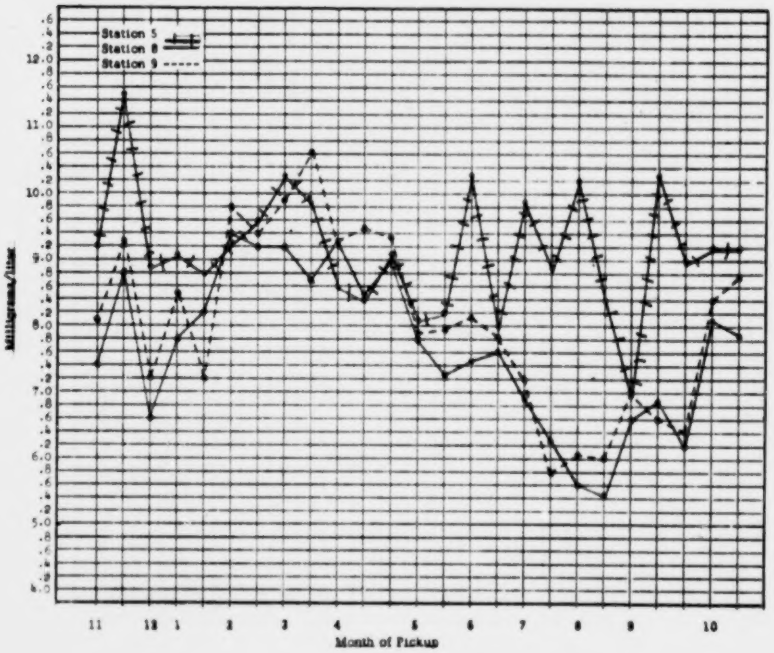

Figure 106. White's Trout Farm. Dissolved Oxygen. Stations 5, 8 and 9.

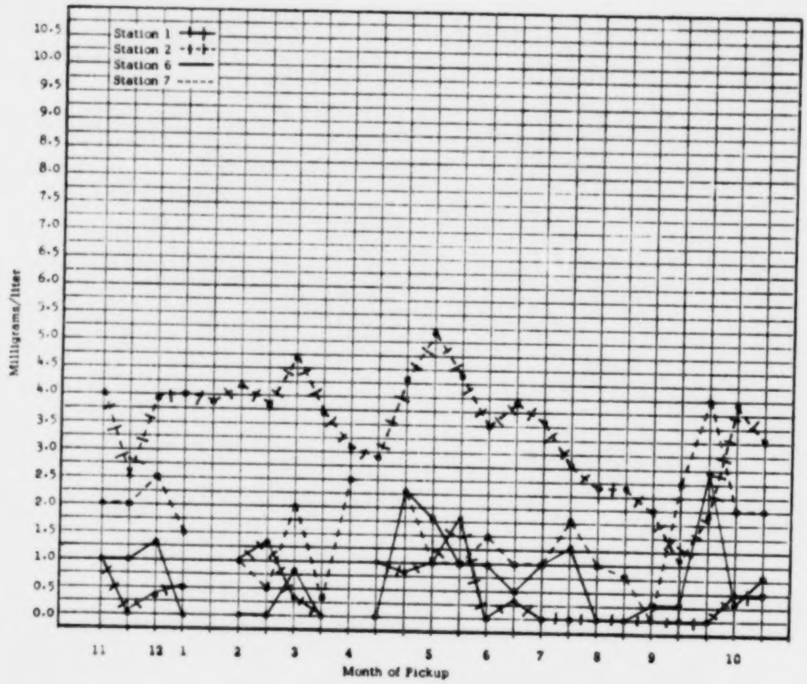

Figure 107. White's Trout Farm. Carbon Dioxide. Stations 1, 2, 6 and 7.

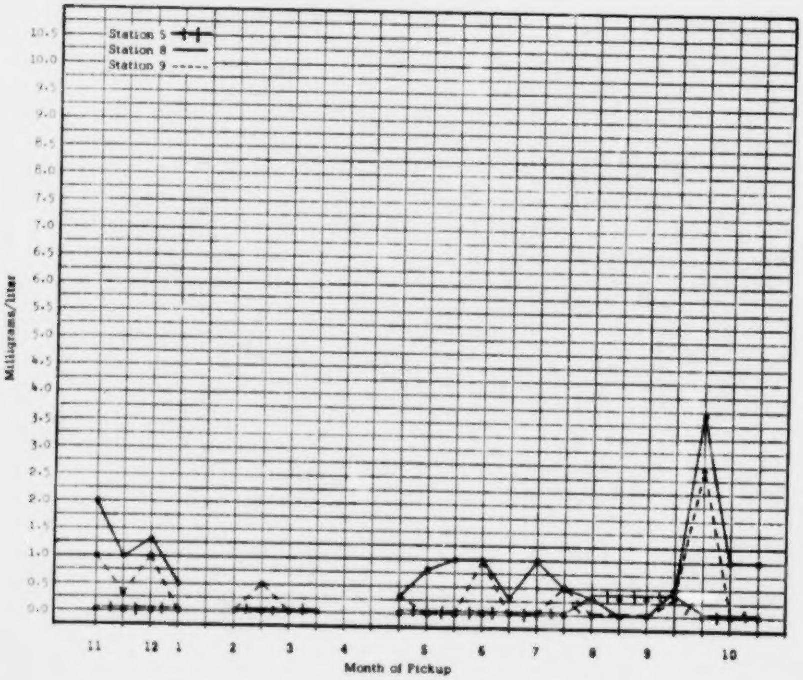

Figure 108. White's Trout Farm. Carbon Dioxide. Stations 5, 8 and 9.

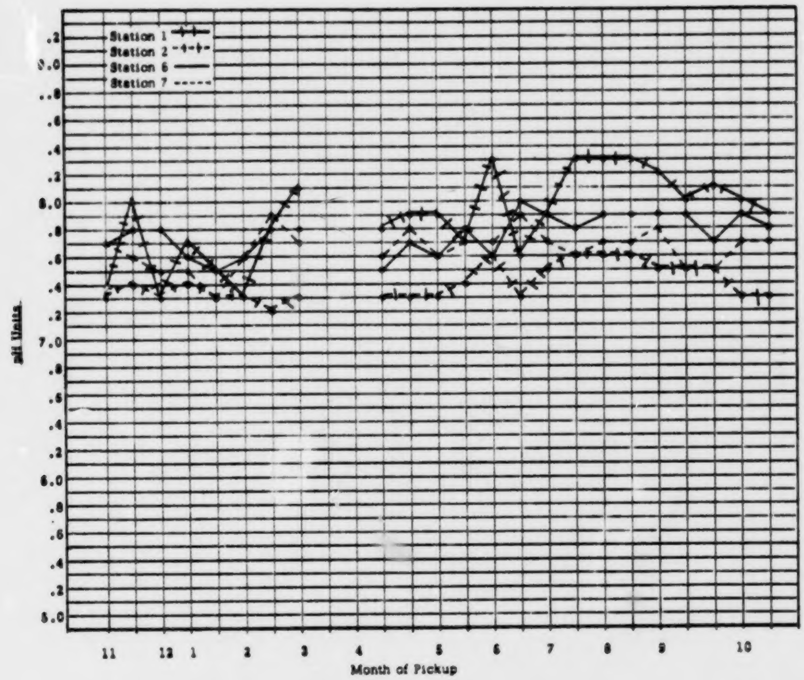

Figure 109. White's Trout Farm, Hydrogen Ion Concentration, Stations 1, 2, 6 and 7.

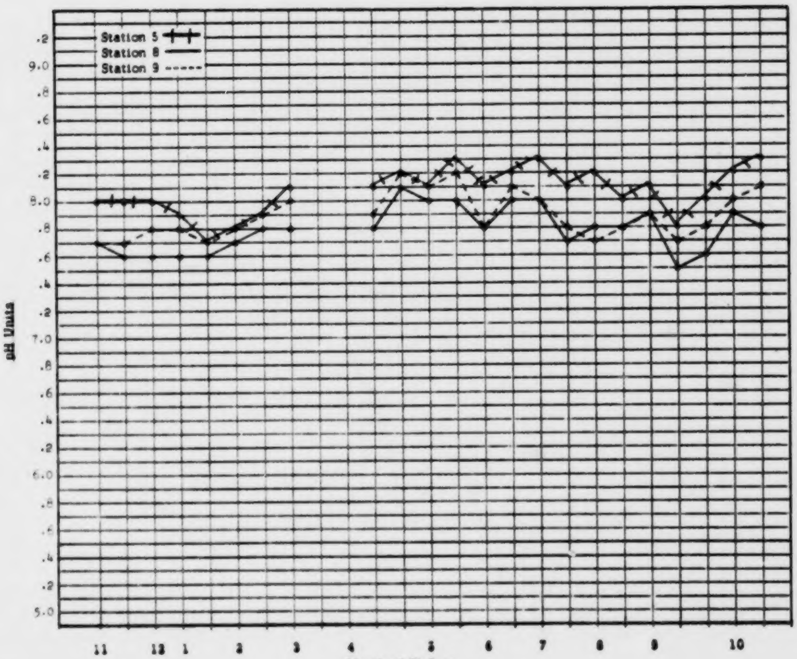

Figure 110. White's Trout Farm, Hydrogen Ion Concentration, Stations 5, 8 and 9.

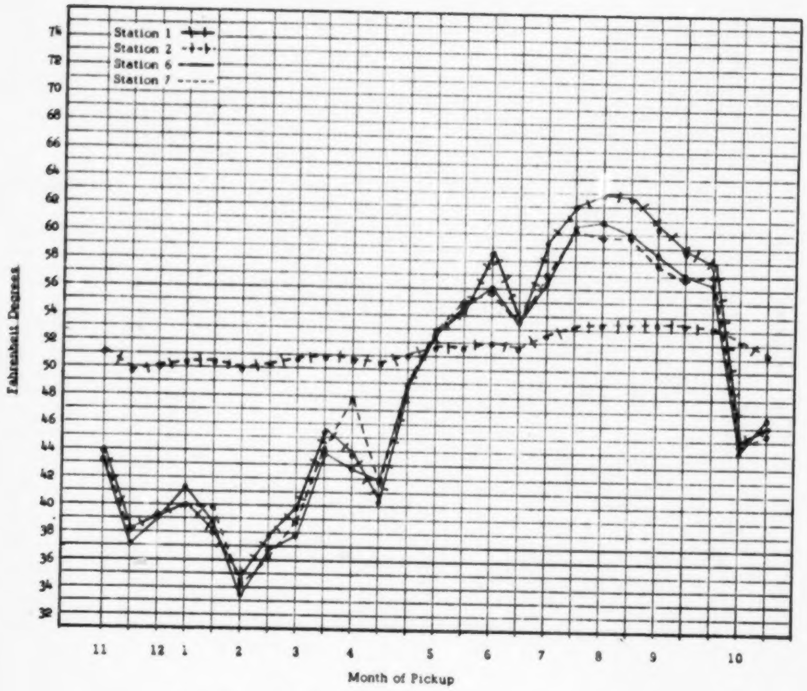

Figure 111. White's Trout Farm. Temperature. Stations 1, 2, 6 and 7.

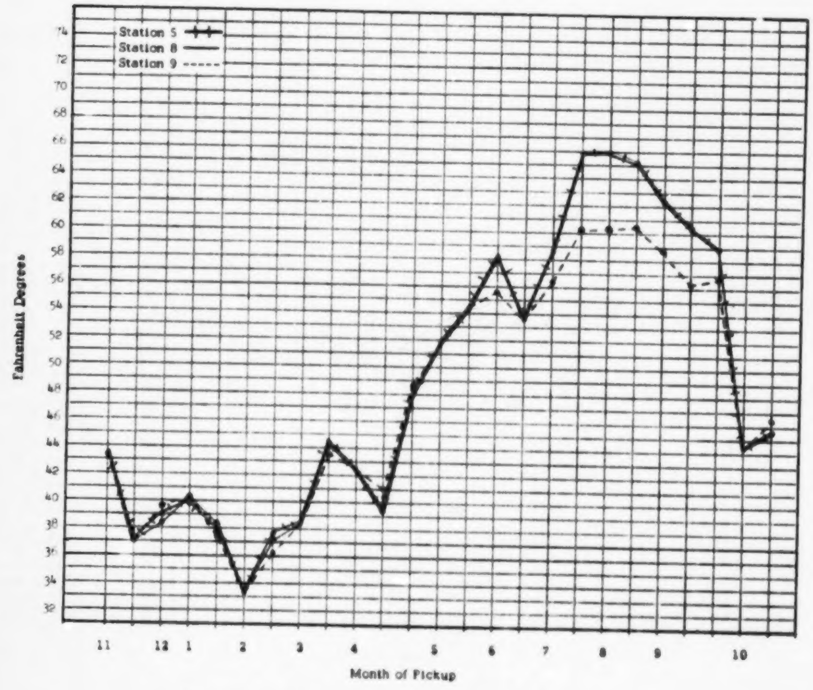

Figure 112. White's Trout Farm. Temperature. Stations 5, 8 and 9.

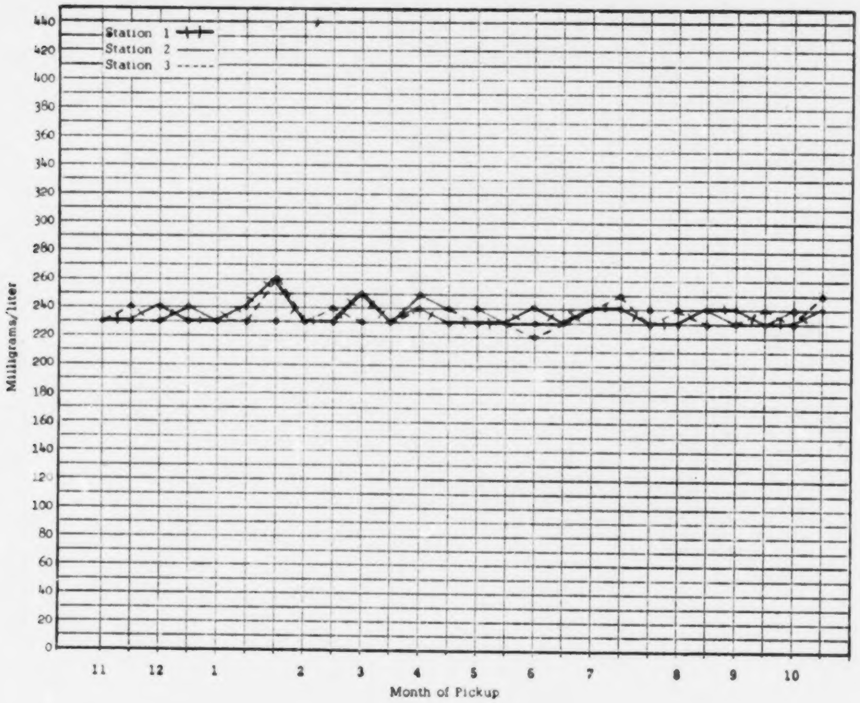

Figure 113. Springville Hatchery (State). M.O. Alkalinity. Stations 1, 2 and3.

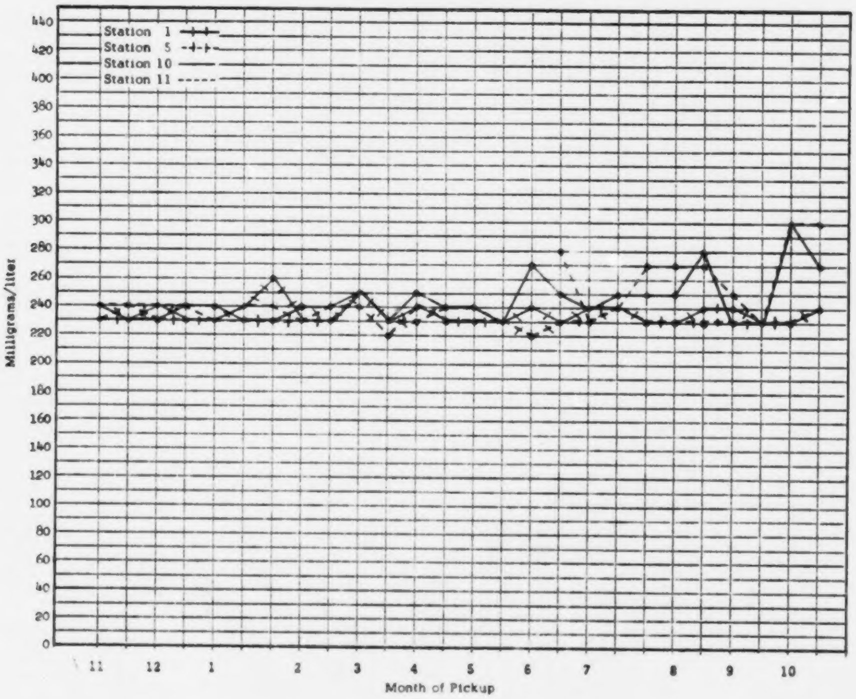

Figure 114. Springville Hatchery (Federal). M.O. Alkalinity. Stations 1, 5, 10 and 11.

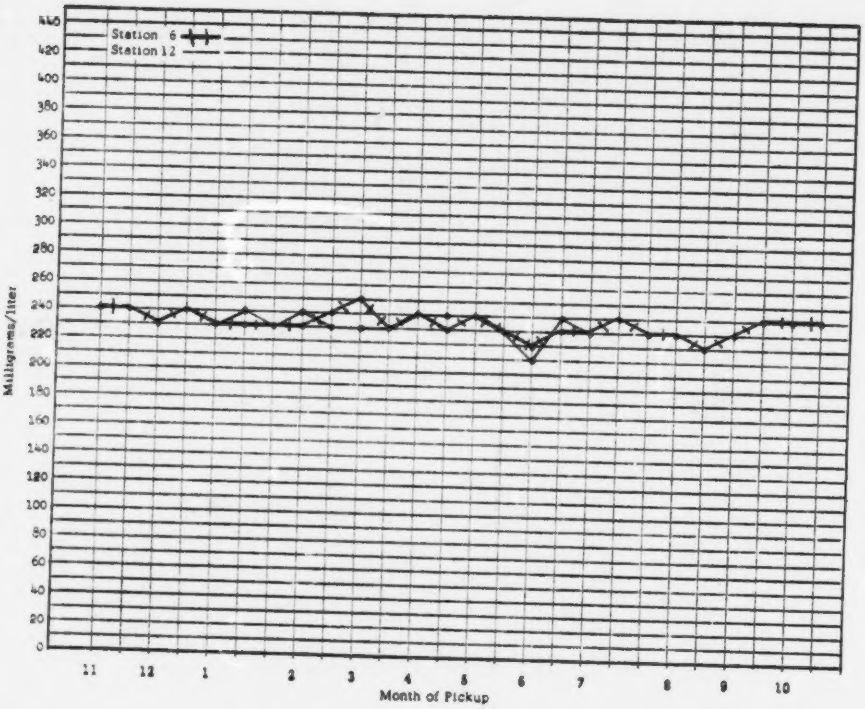

Figure 115. Springville Hatchery (Federal, Pond). M.O. Alkalinity. Stations 6 and 12.

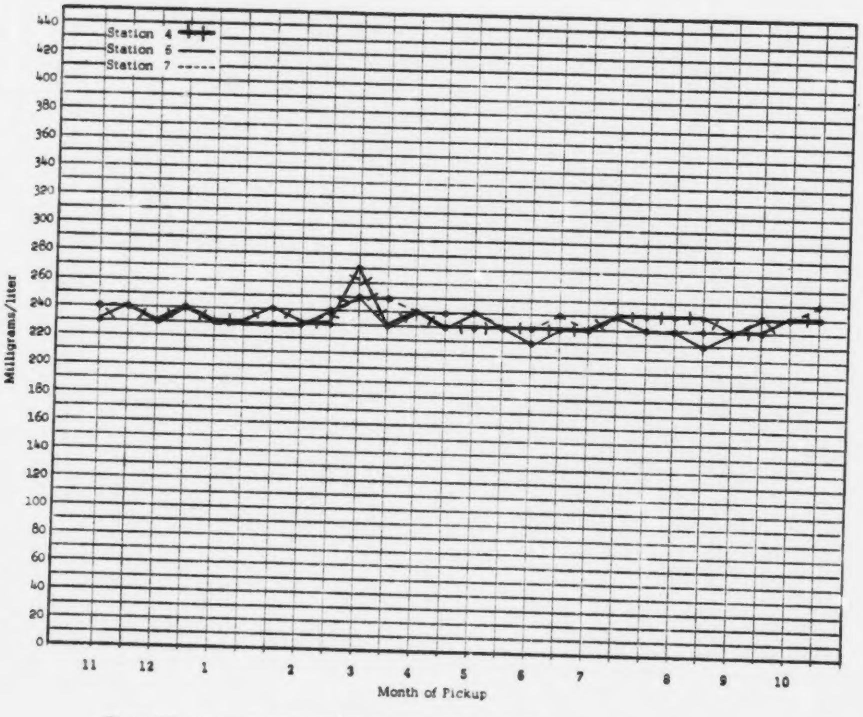

Figure 116. Springville Hatchery (Receiving Water). M.O. Alkalinity. Stations 4, 6 and 7.

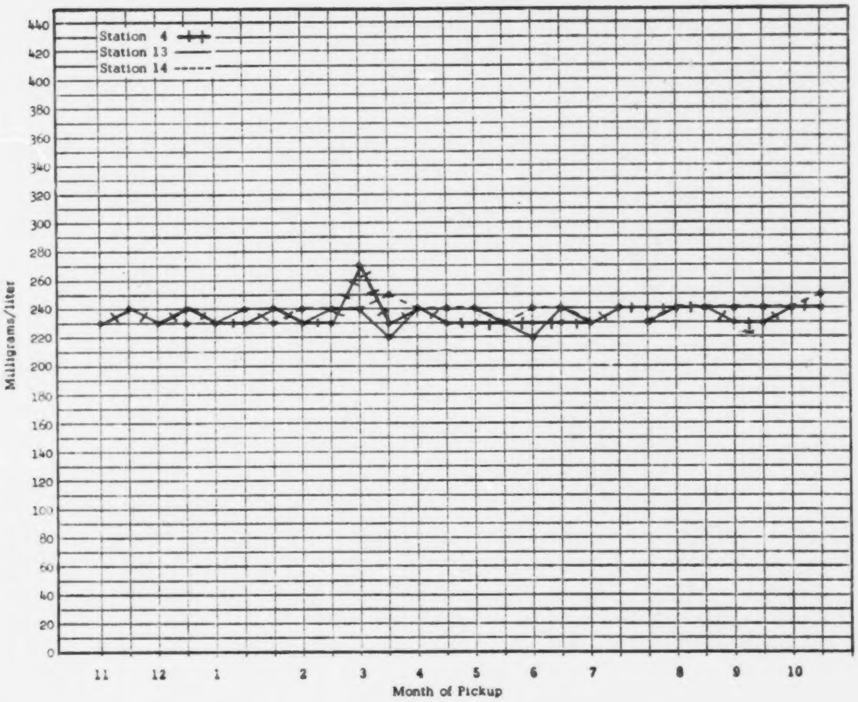

Figure 117. Springville Hatchery (Receiving water). M.O. Alkalinity. Stations 4, 13 and 14.

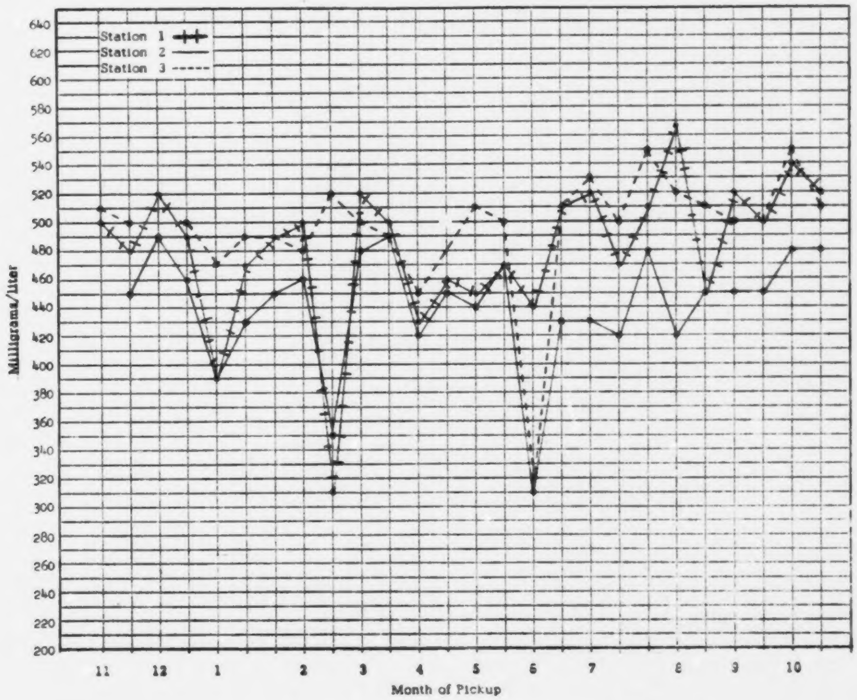

Figure 118. Springville Hatchery (State). Total Hardness. Stations 1, 2, and 3.

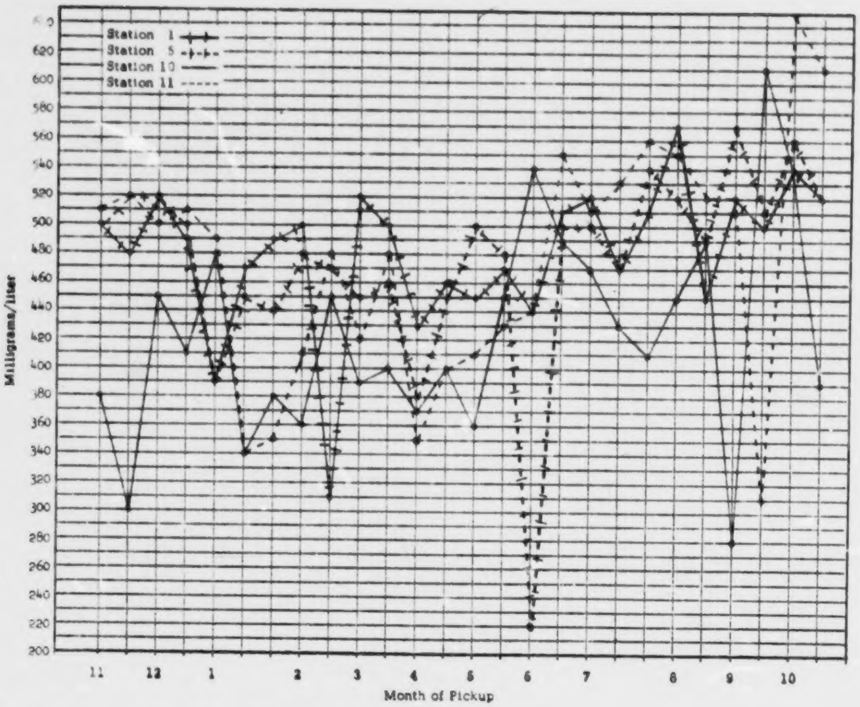

Figure 119. Springville Hatchery (Federal). Total Hardness. Stations 1, 5, 10 and 11.

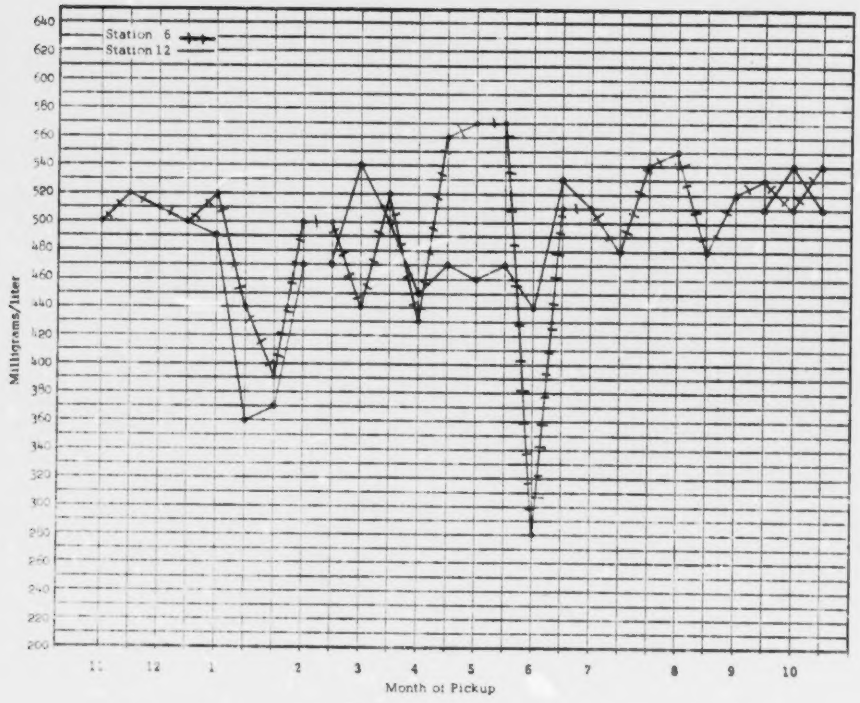

Figure 120. Springville Hatchery (Federal pond). Total Hardness. Stations 6 and 12.

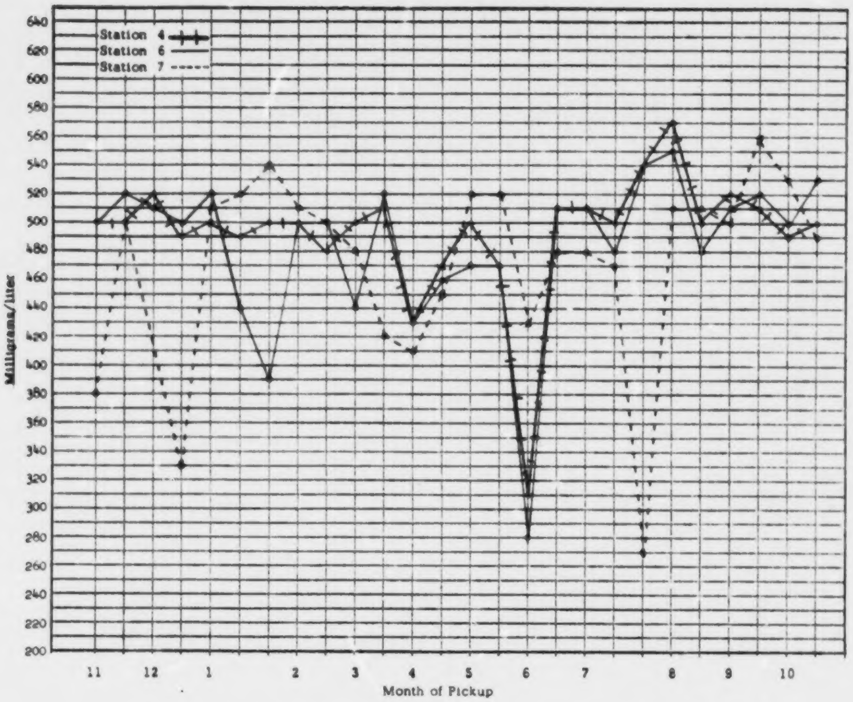

Figure 121. Springville Hatchery (Receiving water), Total Hardness. Stations 4, 6 and 7.

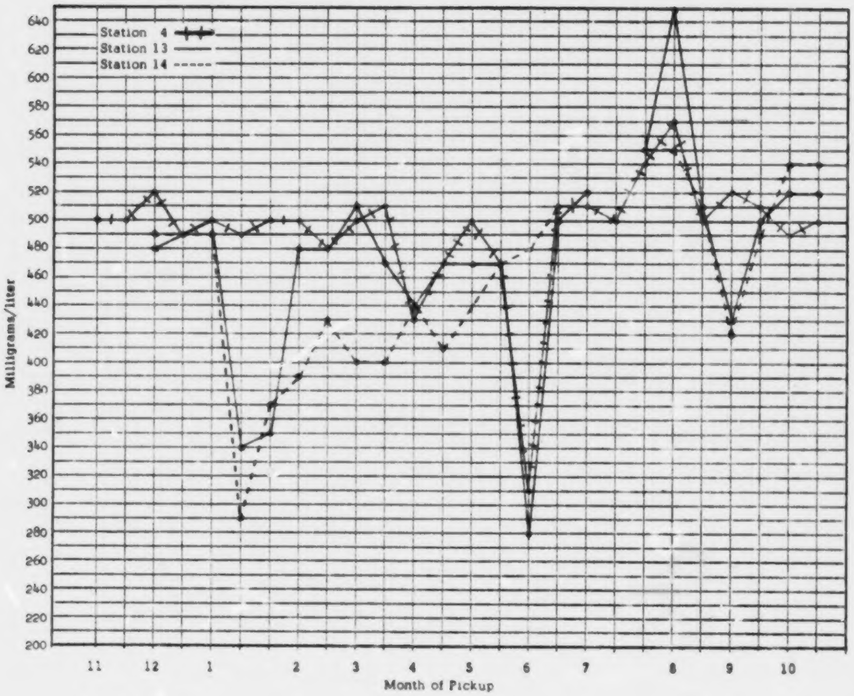

Figure 122. Springville Hatchery (Receiving water), Total Hardness. Stations 4, 13 and 14.

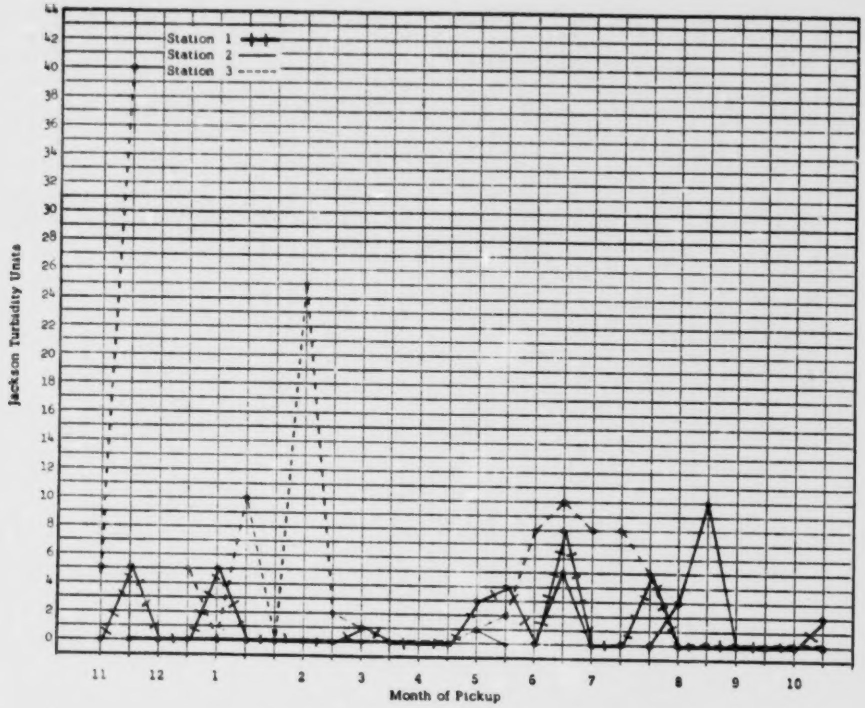

Figure 123. Springville Hatchery (State). Turbidity. Stations 1, 2 and 3.

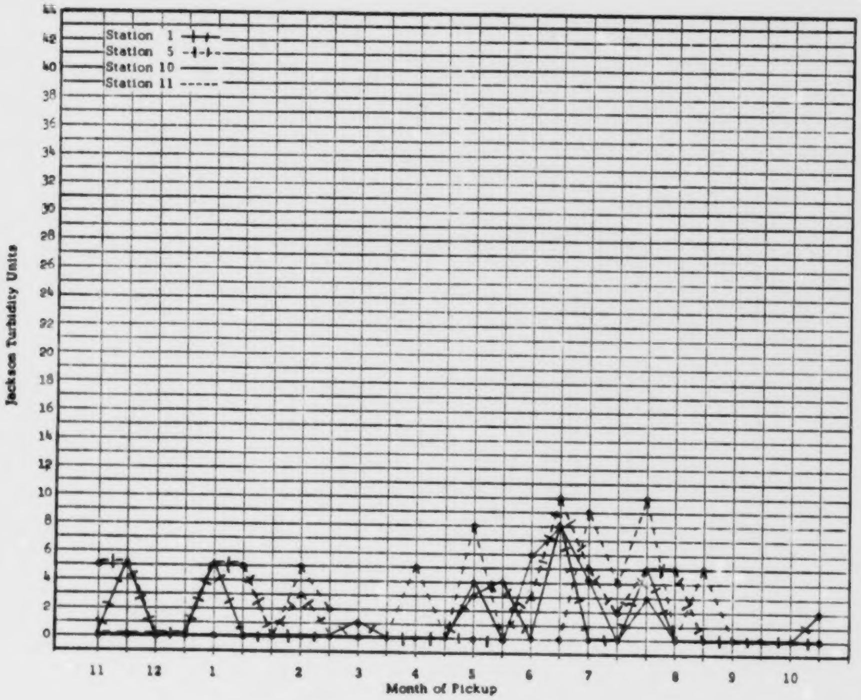

Figure 124. Springville Hatchery (Federal). Turbidity. Stations 1, 5, 10 and 11.

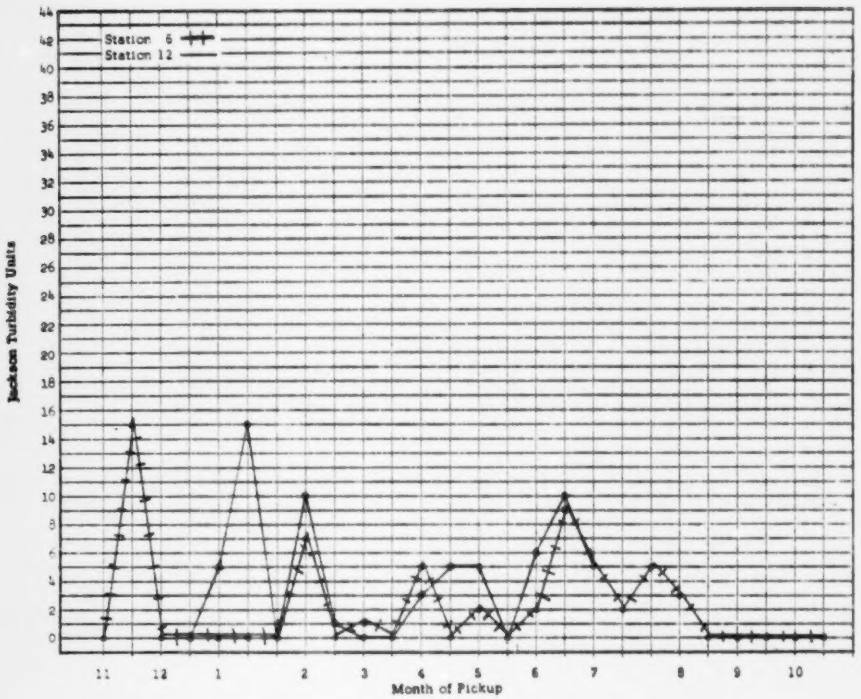

Figure 125. Springville Hatchery (Federal pond), Turbidity. Stations 6 and 12.

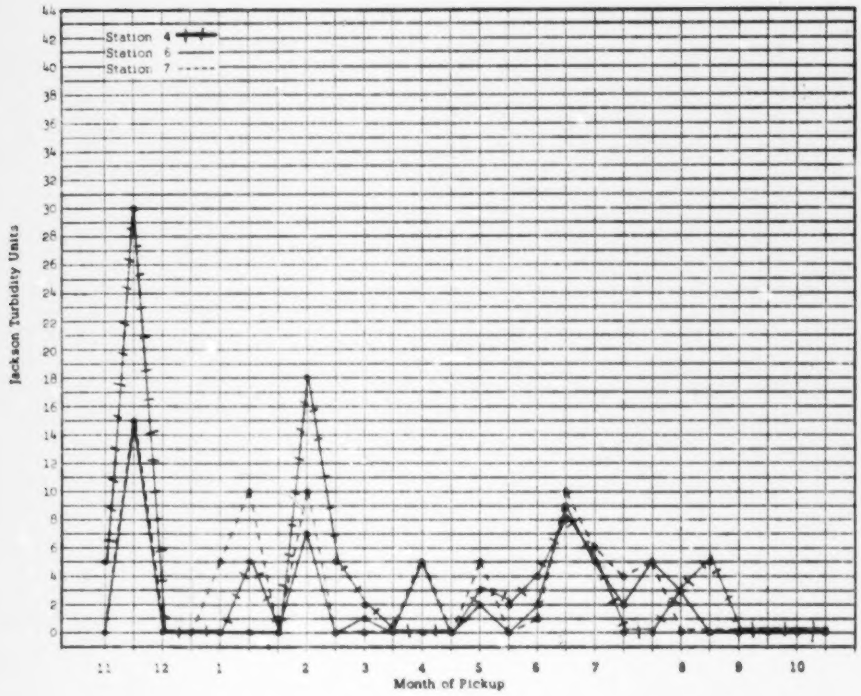

Figure 126. Springville Hatchery (Receiving water), Turbidity. Stations 4, 6 and 7.

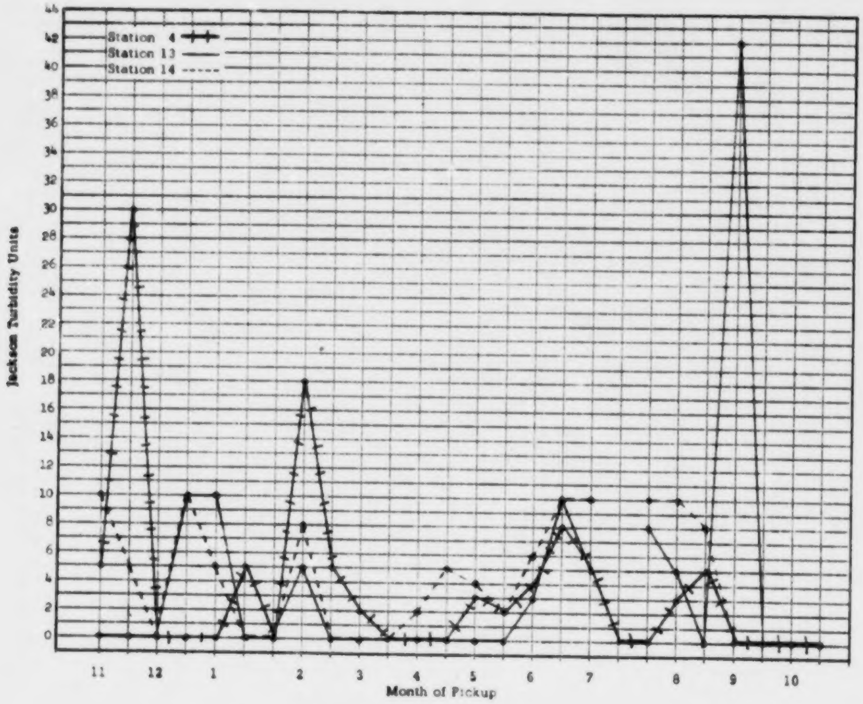

Figure 127. Springville Hatchery (Receiving water). Turbidity. Stations 4, 13 and 14.

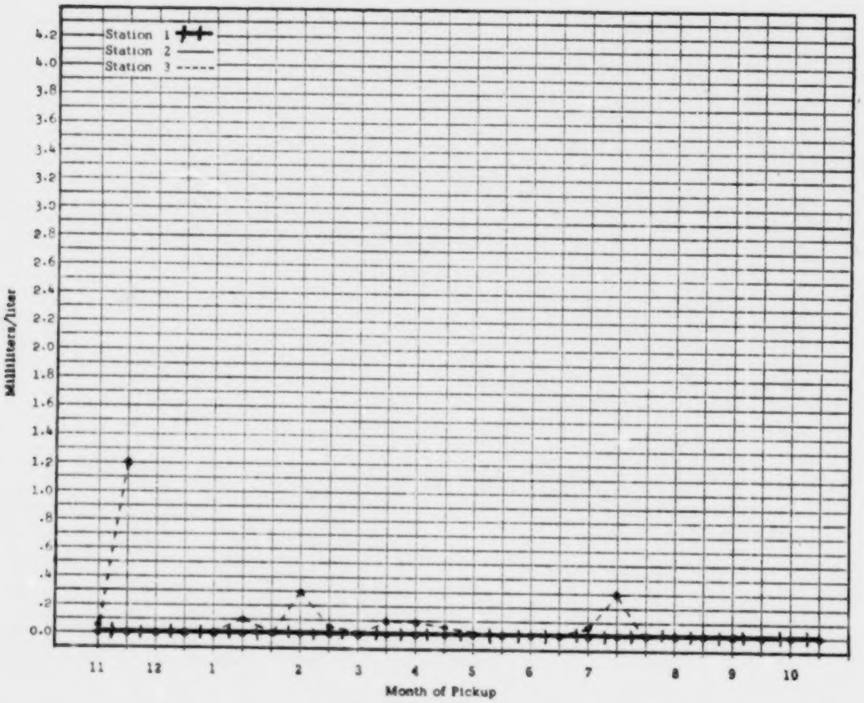

Figure 128. Springville Hatchery (State). Settleable Solids. Stations 1, 2 and 3.

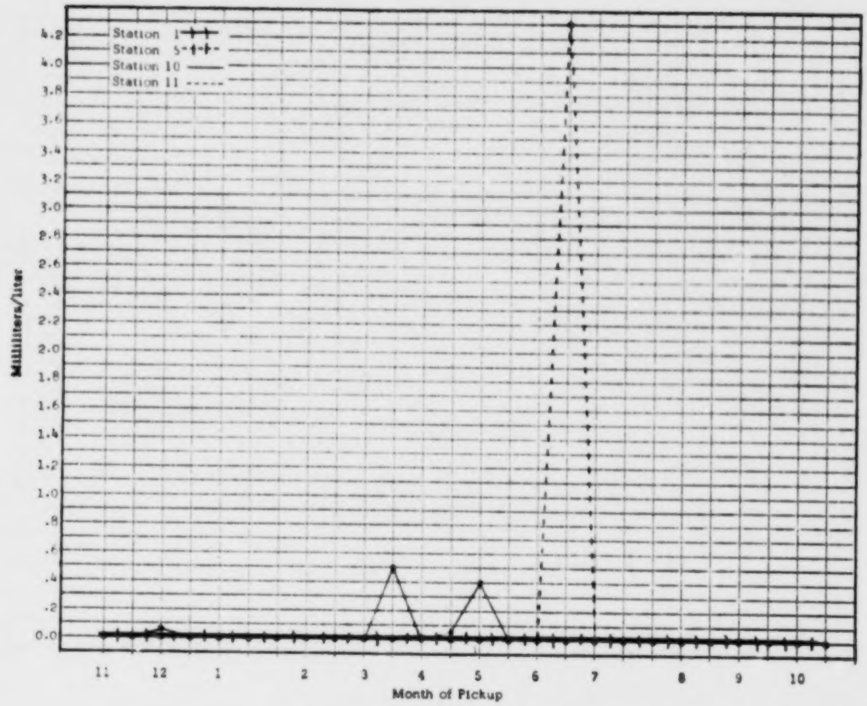

Figure 129. Springville Hatchery (Federal). Settleable Solids. Stations 1, 5, 10 and 11.

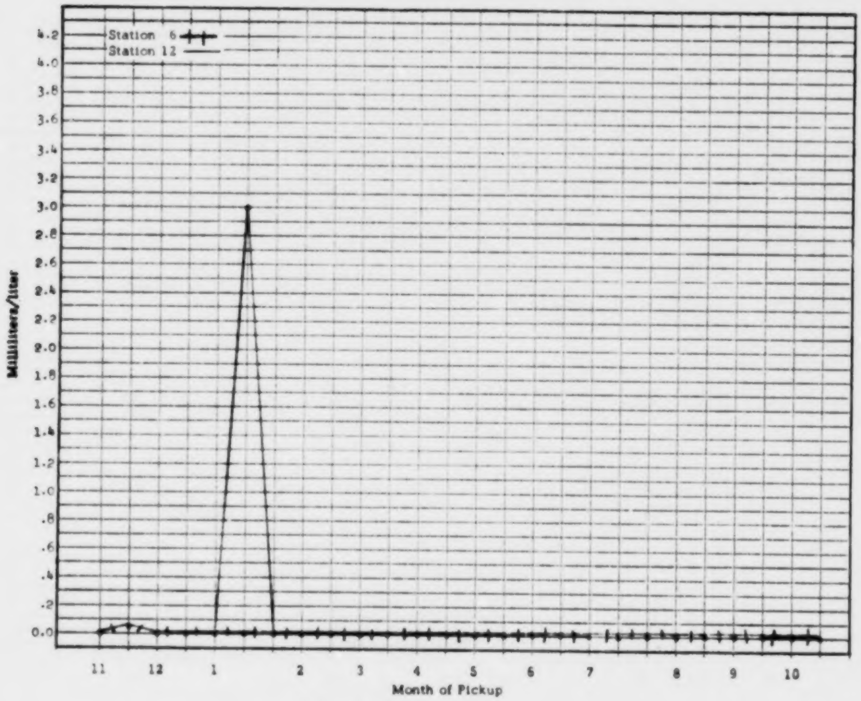

Figure 130. Springville Hatchery (Federal pond). Settleable Solids. Stations 6 and 12.

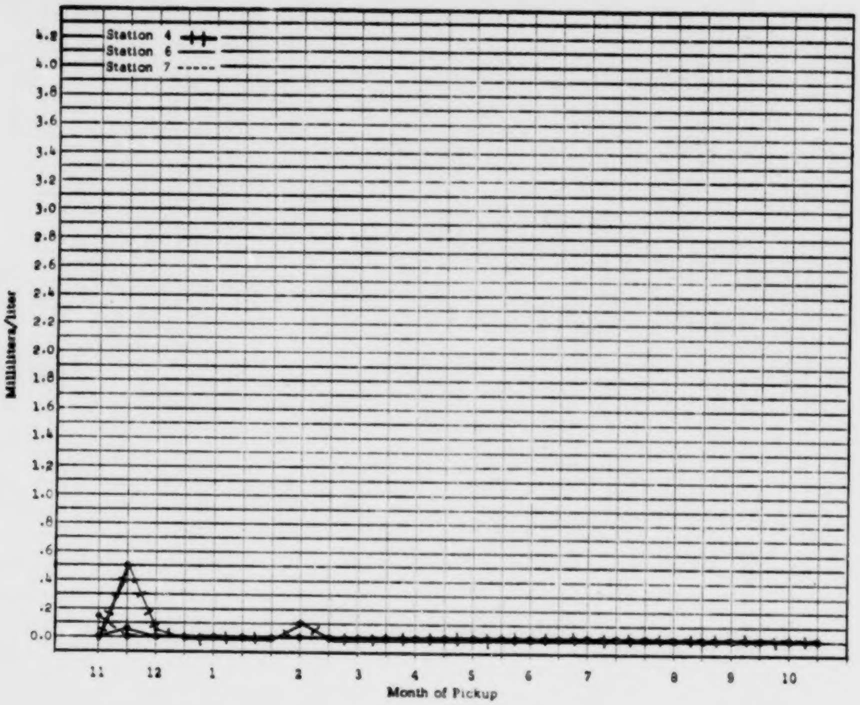

Figure 131. Springville Hatchery (Receiving water). Settleable Solids. Stations 4, 6 and 7.

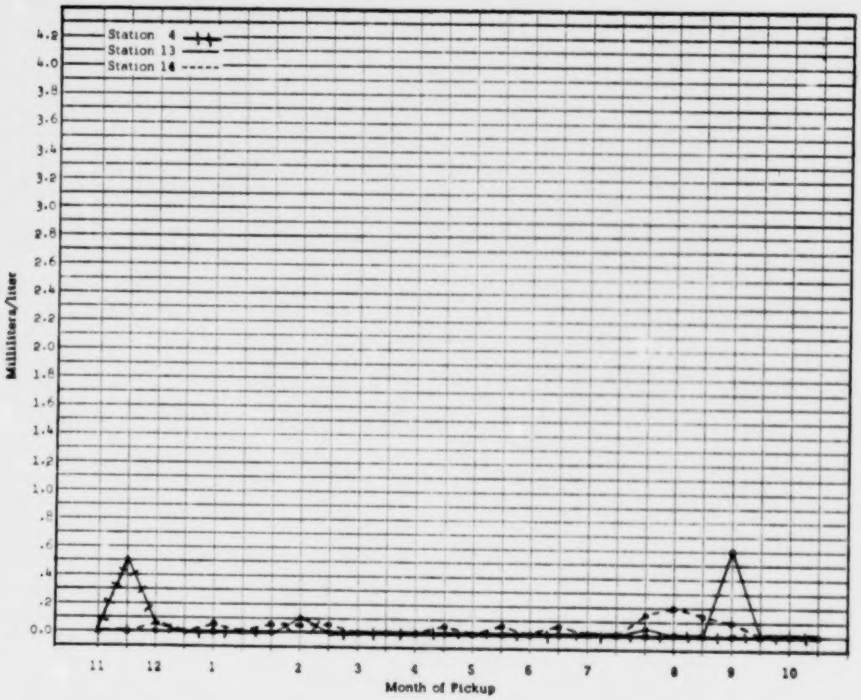

Figure 132. Springville Hatchery (Receiving water). Settleable Solids. Stations 4, 13 and 14.

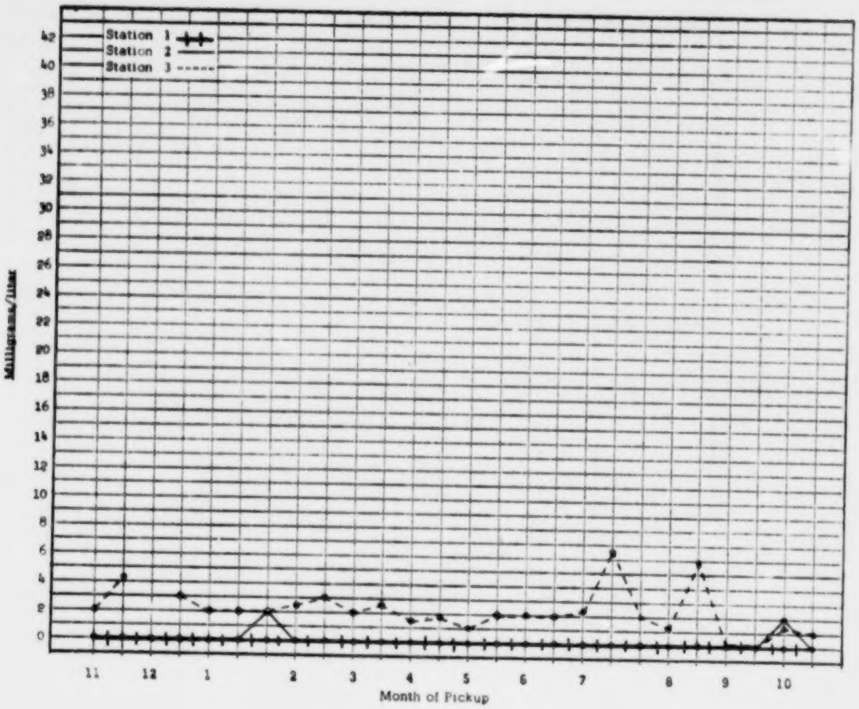

Figure 133. Springville Hatchery (State). Suspended Solids. Stations 1, 2 and 3.

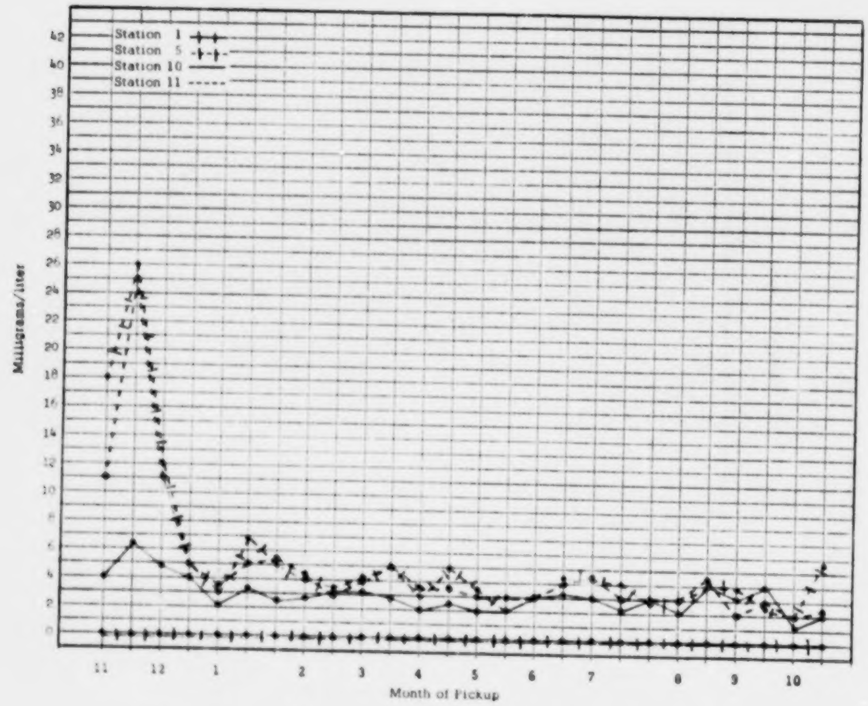

Figure 134. Springville Hatchery (Federal). Suspended Solids. Stations 1, 5, 10 and 11.

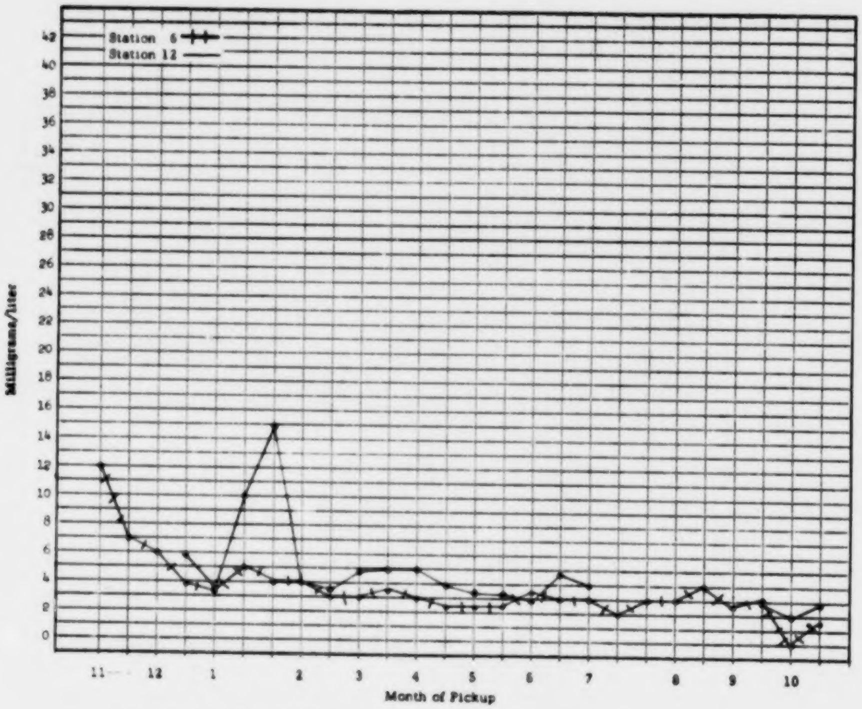

Figure 135. Springville Hatchery (Federal pond). Suspended Solids. Stations 6 and 12.

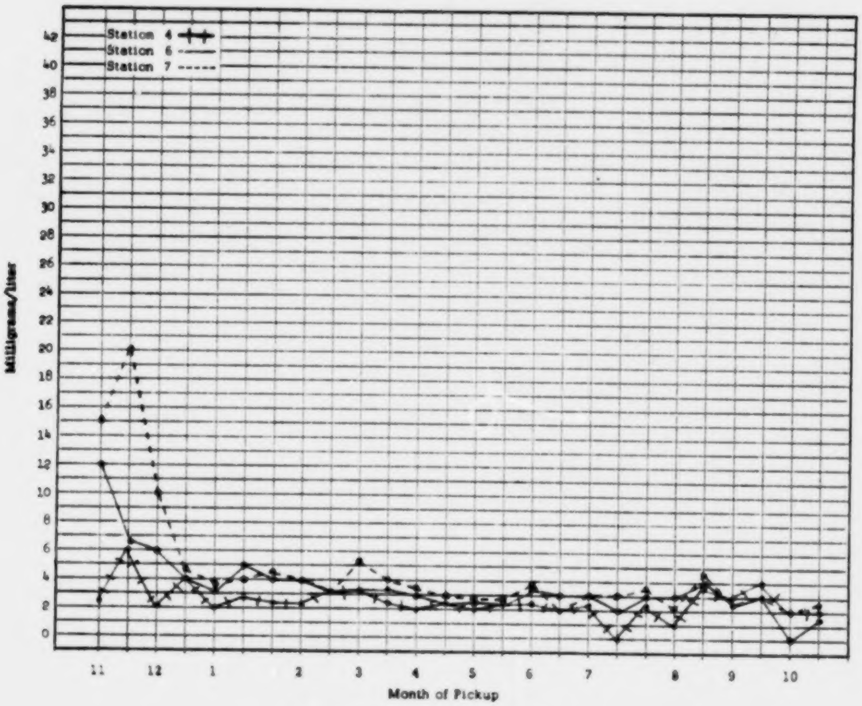

Figure 136. Springville Hatchery (Receiving water). Suspended Solids. Stations 4, 6 and 7.

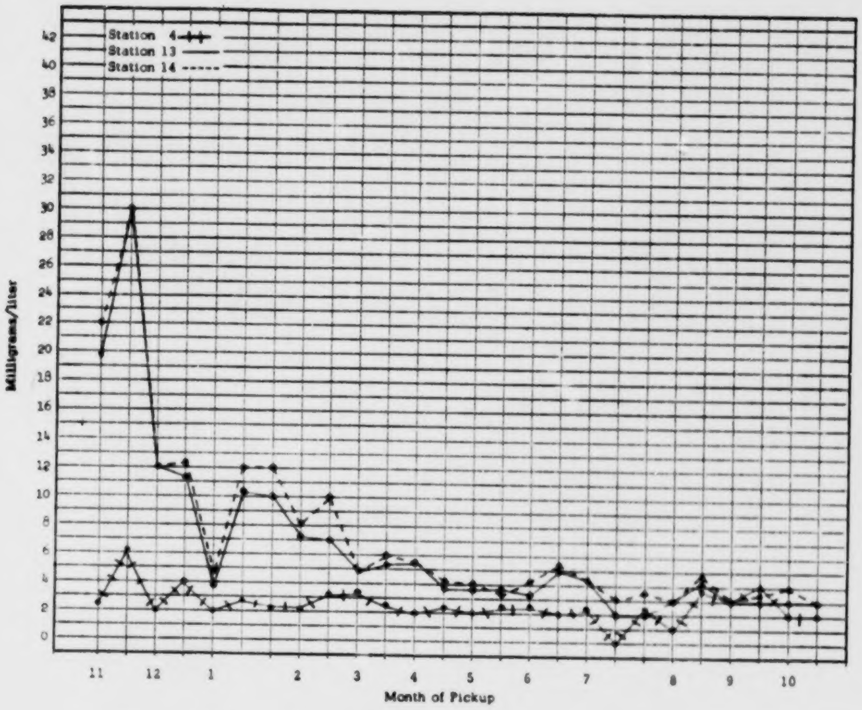

Figure 137. Springville Hatchery (Receiving water), Suspended Solids. Stations 4, 13 and 14.

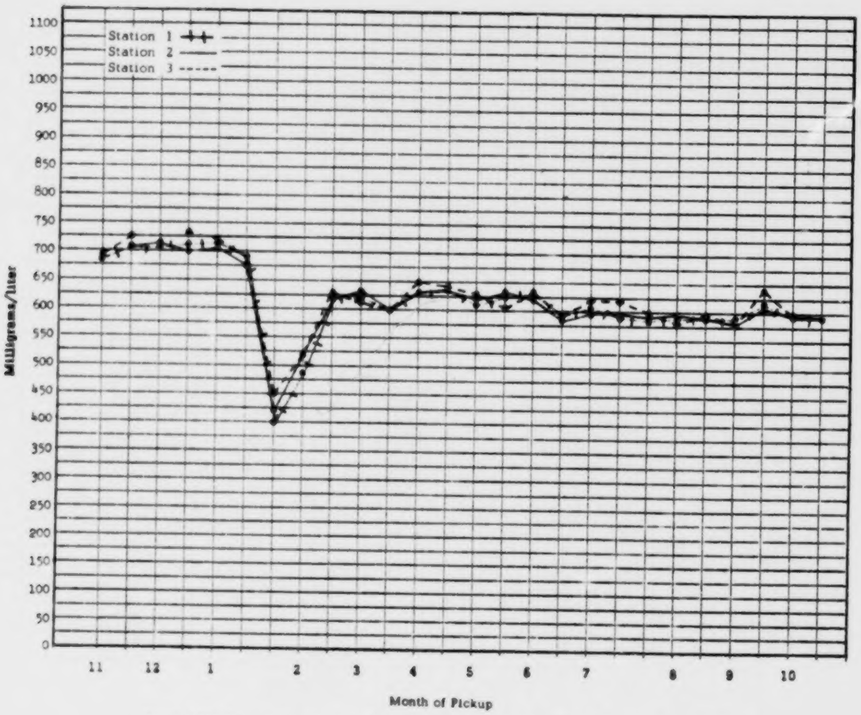

Figure 138. Springville Hatchery (State), Total Dissolved Solids. Stations 1, 2 and 3.

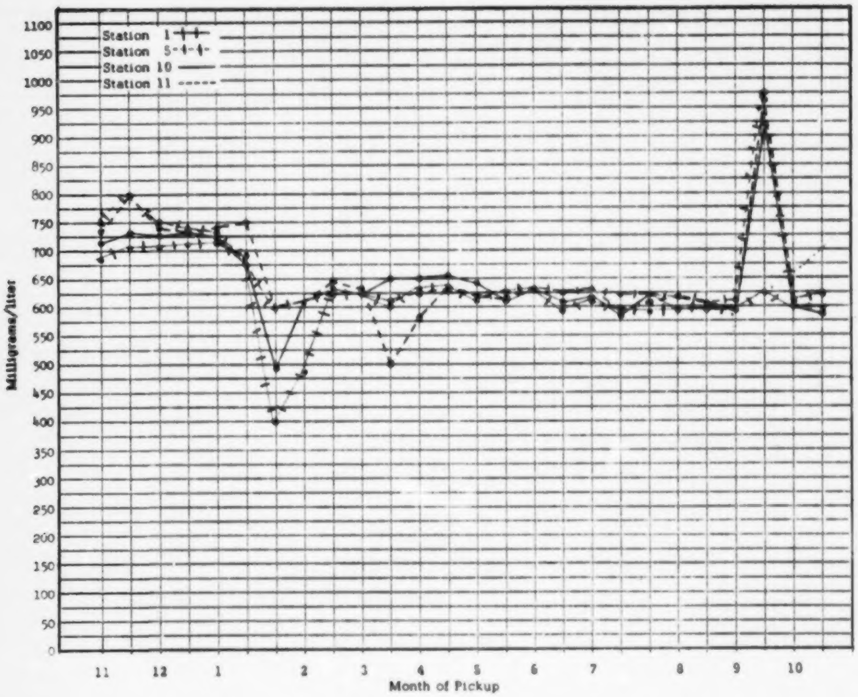

Figure 139. Springville Hatchery (Federal), Total Dissolved Solids. Stations 1, 5, 10 and 11.

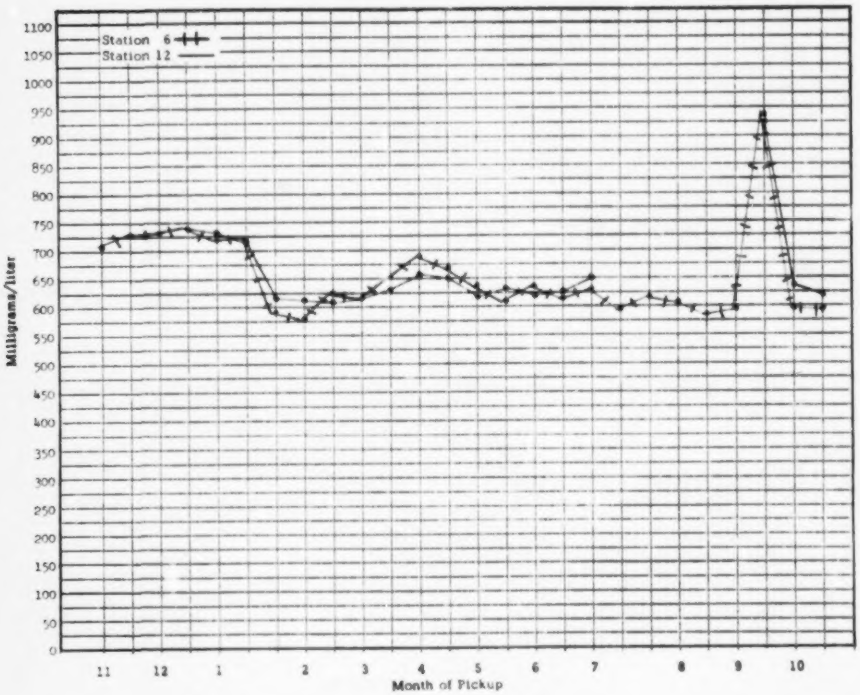

Figure 140. Springville Hatchery (Federal pond), Total Dissolved Solids. Stations 6 and 12.

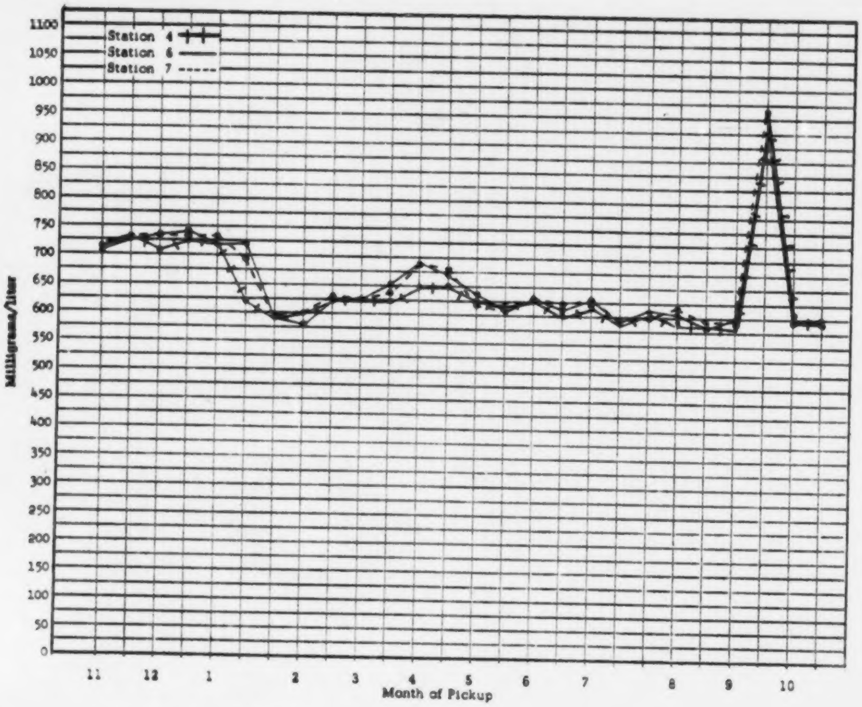

Figure 141. Springville Hatchery (Receiving water), Total Dissolved Solids. Stations 4, 6 and 7.

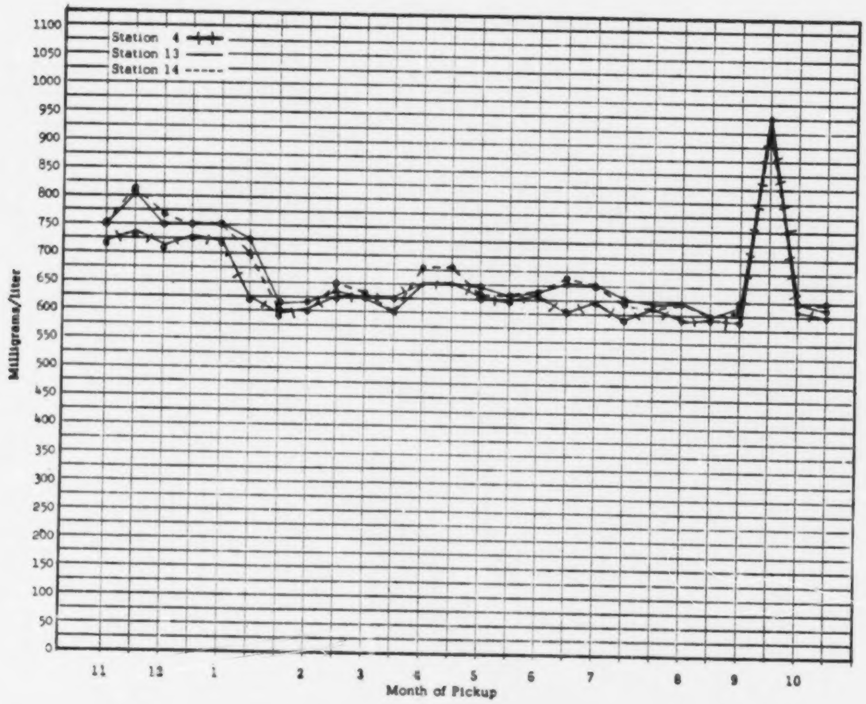

Figure 142. Springville Hatchery (Receiving water). Total Dissolved Solids. Stations 4, 13 and 14.

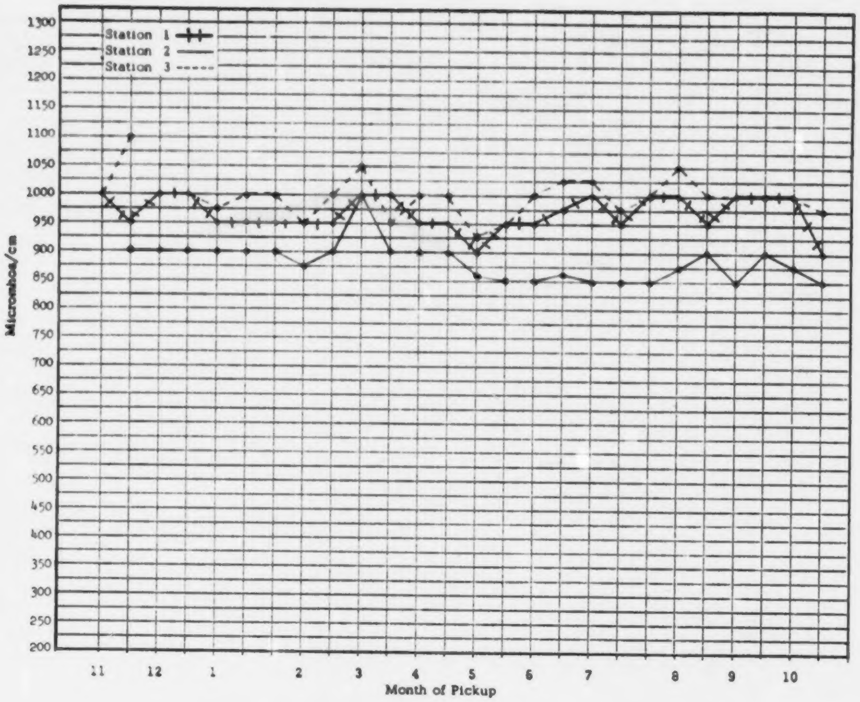

Figure 143. Springville Hatchery (State), Specific Conductance. Stations 1, 2 and 3.

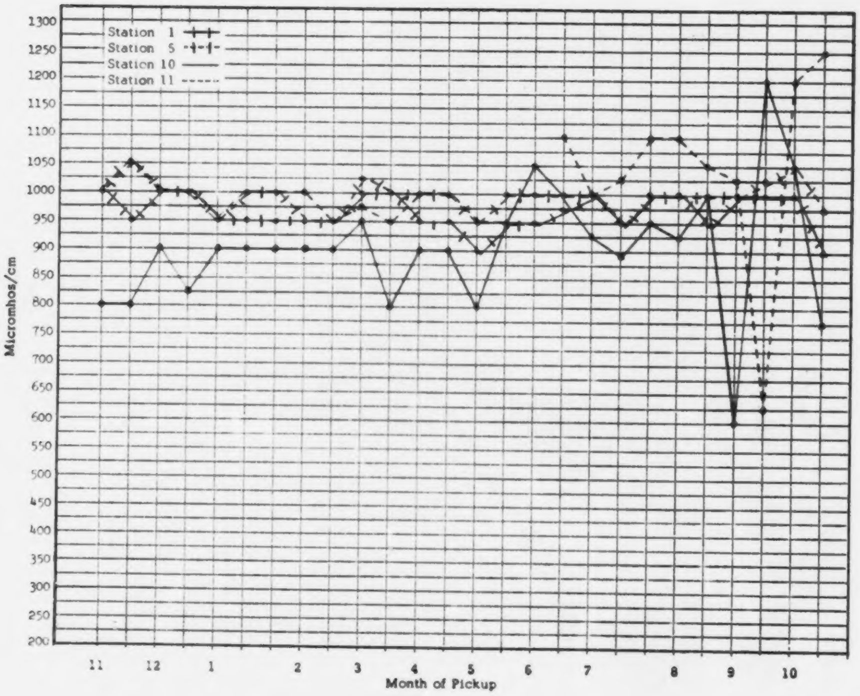

Figure 144. Springville Hatchery (Federal), Specific Conductance. Stations 1, 5, 10 and 11.

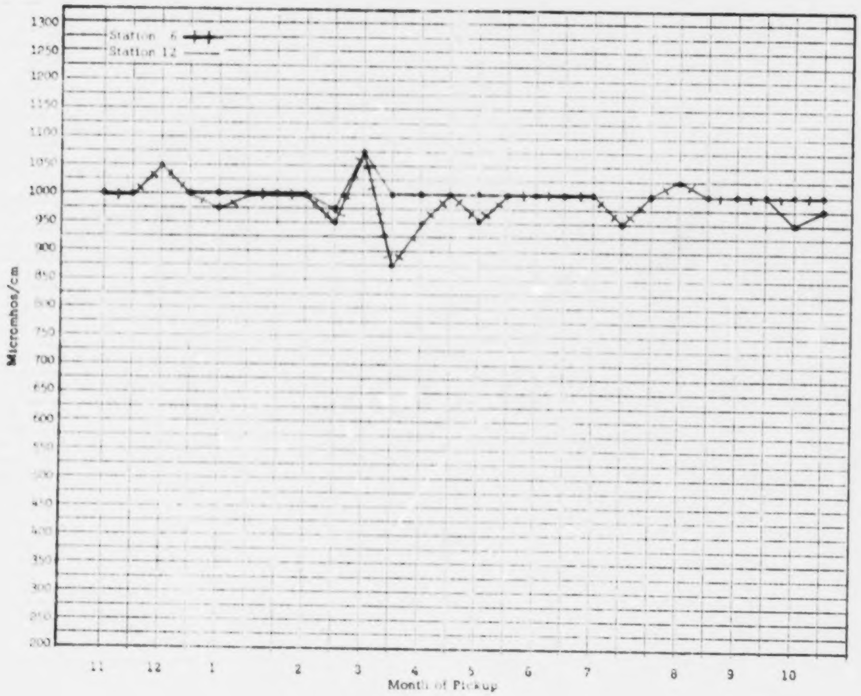

Figure 145. Springville Hatchery (Federal pond). Specific Conductance. Stations 6 and 12.

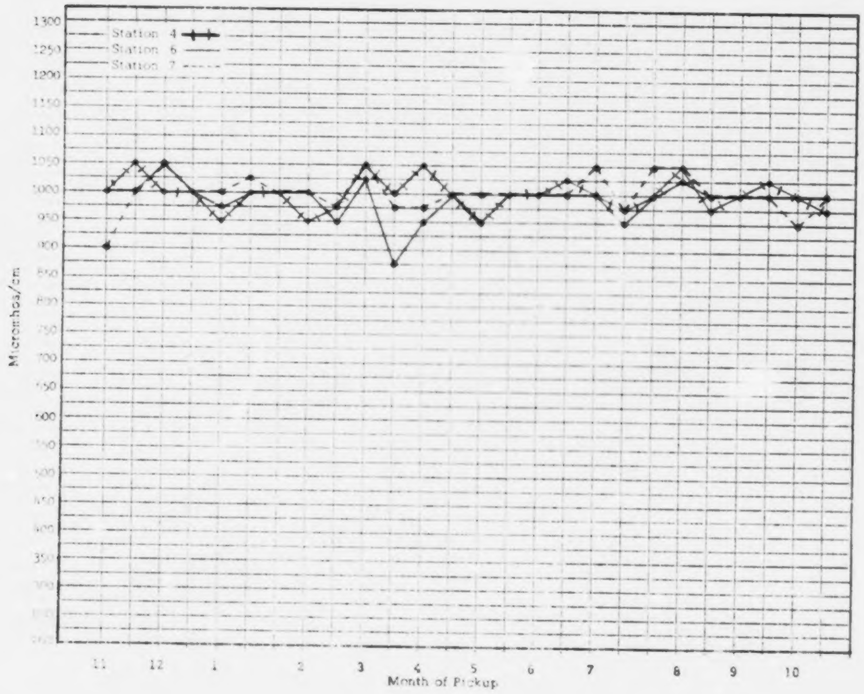

Figure 146. Springville Hatchery (Receiving water). Specific Conductance. Stations 4, 6 and 7.

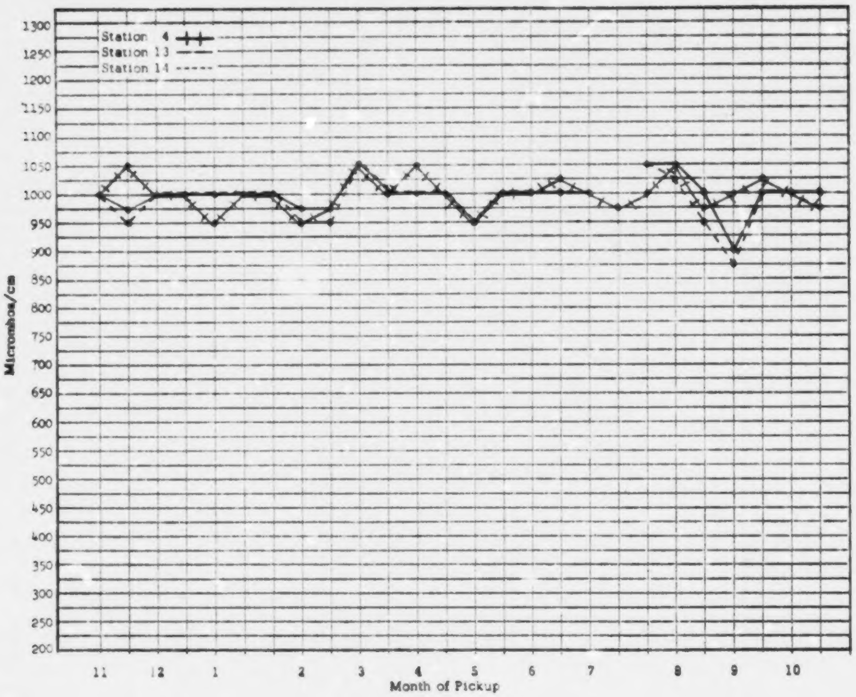

Figure 147. Springville Hatchery (Receiving water), Specific Conductance. Stations 4, 13 and 14.

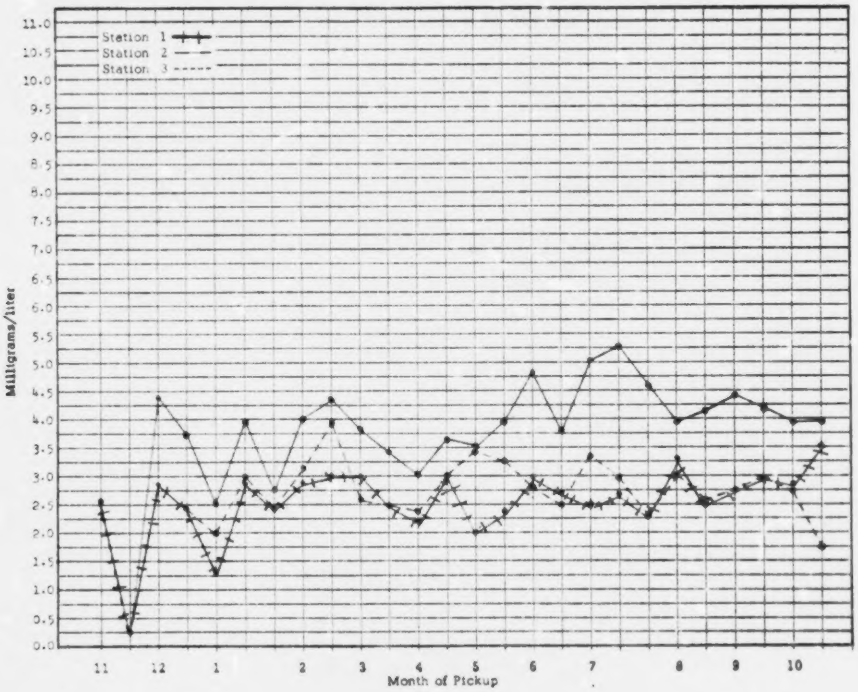

Figure 148. Springville Hatchery (State), Nitrate. Stations 1, 2 and 3.

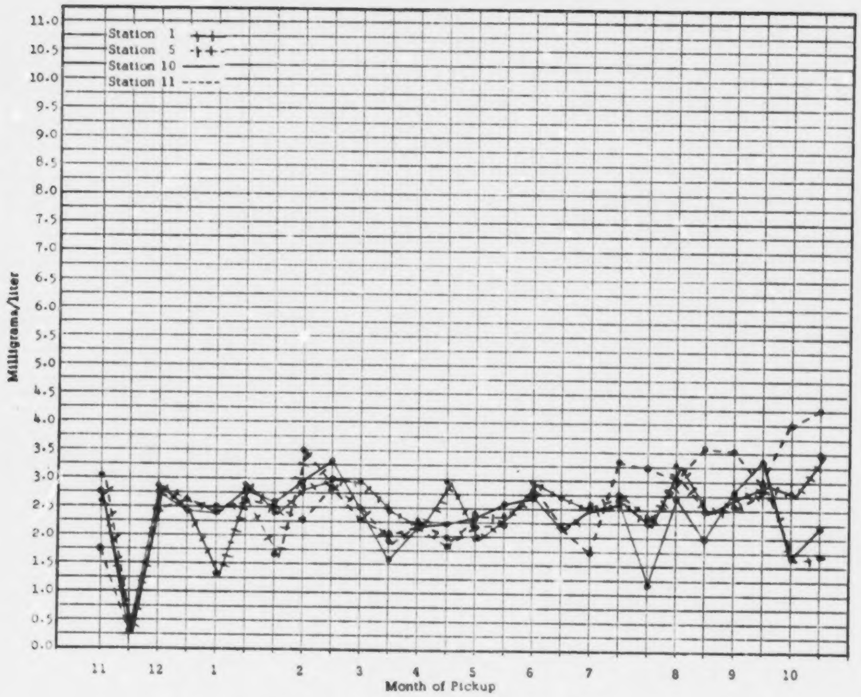

Figure 149. Springville Hatchery (Federal). Nitrate. Stations 1, 5, 10 and 11.

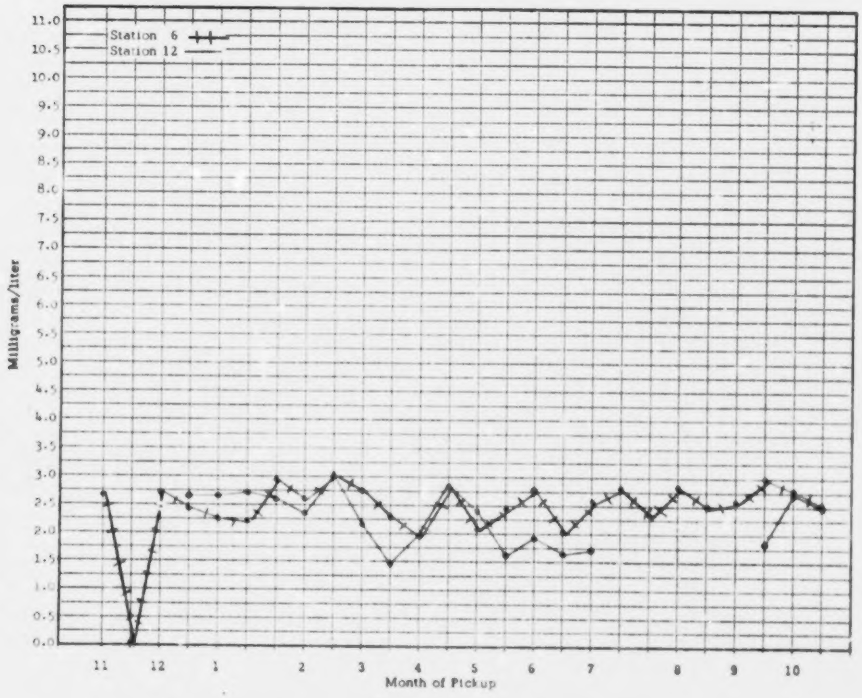

Figure 150. Springville Hatchery (Federal pond). Nitrate. Stations 6 and 12.

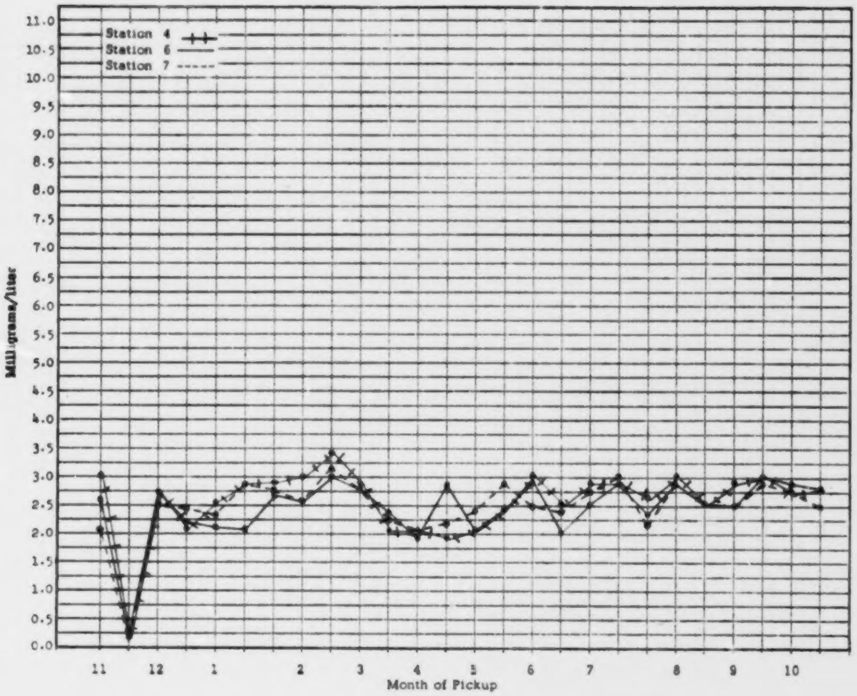

Figure 151. Springville Hatchery (Receiving water), Nitrate. Stations 4, 6 and 7.

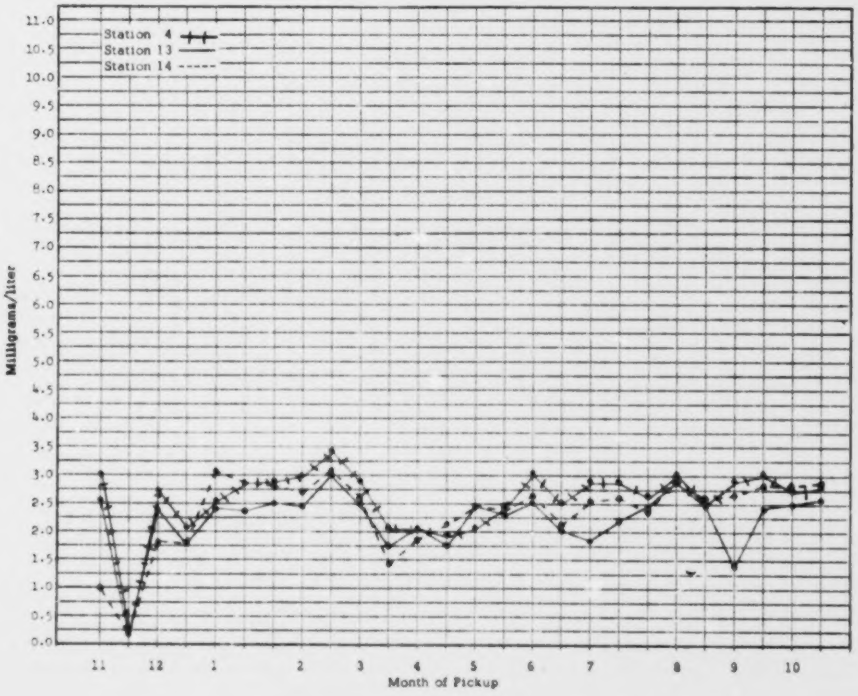

Figure 152. Springville Hatchery (Receiving water), Nitrate. Stations 4, 13 and 14.

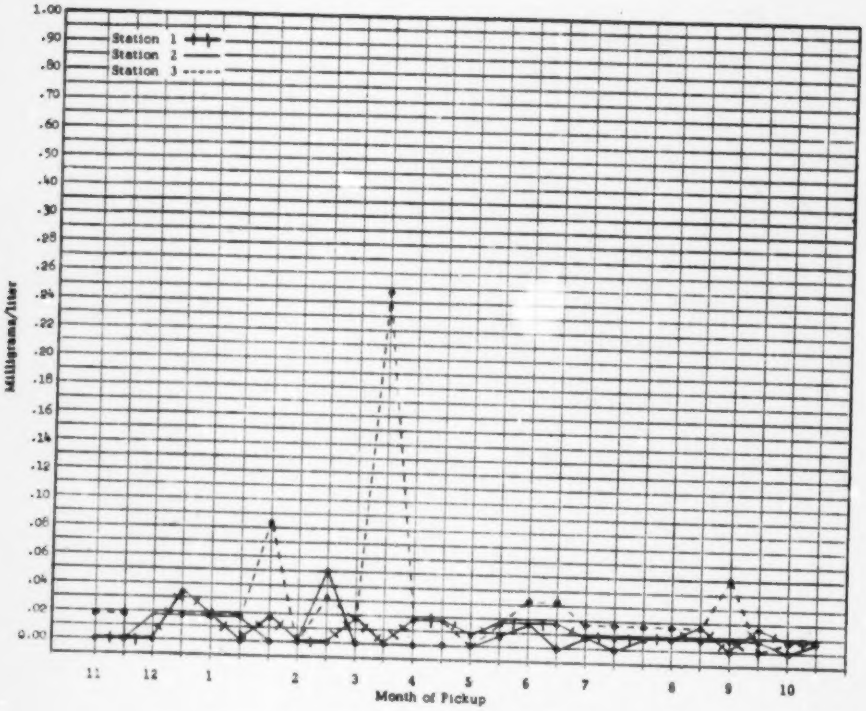

Figure 153. Springville Hatchery (State). Nitrite. Stations 1, 2 and 3.

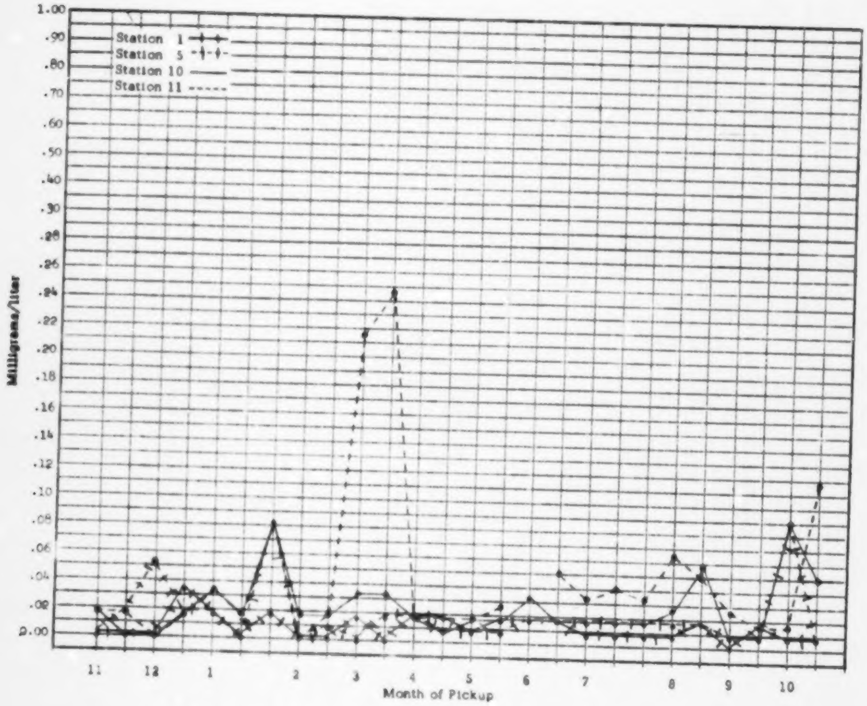

Figure 154. Springville Hatchery (Federal). Nitrite. Stations 1, 5, 10 and 11.

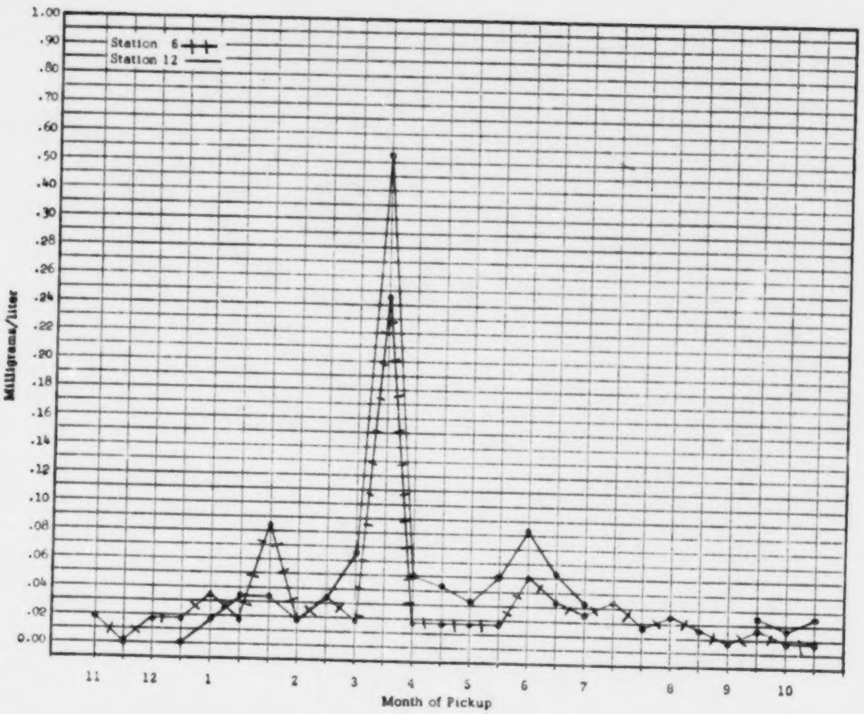

Figure 155. Springville Hatchery (Federal pond), Nitrite. Stations 6 and 12.

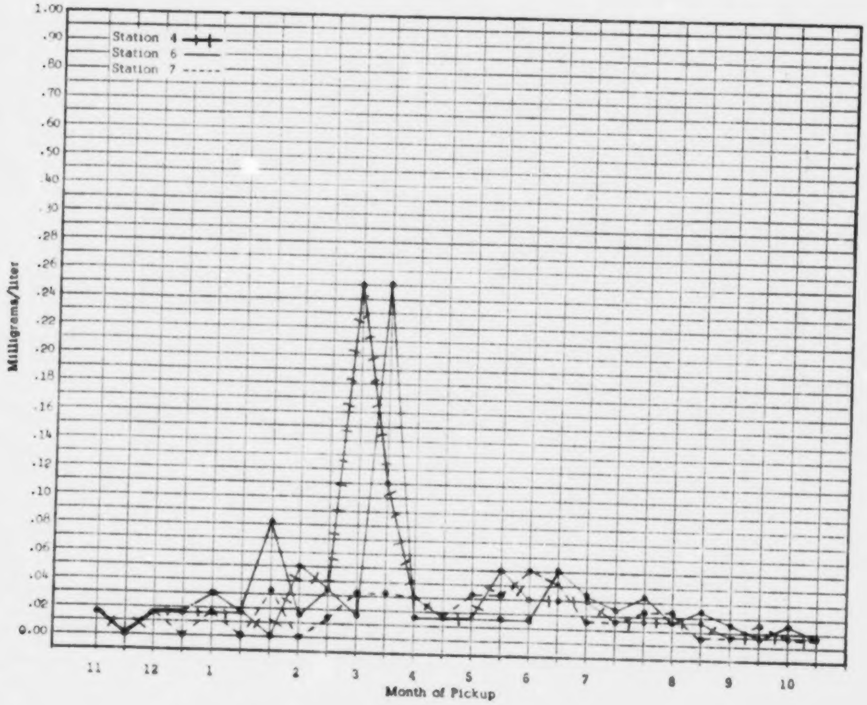

Figure 156. Springville Hatchery (Receiving water). Nitrite. Stations 4, 6 and 7.

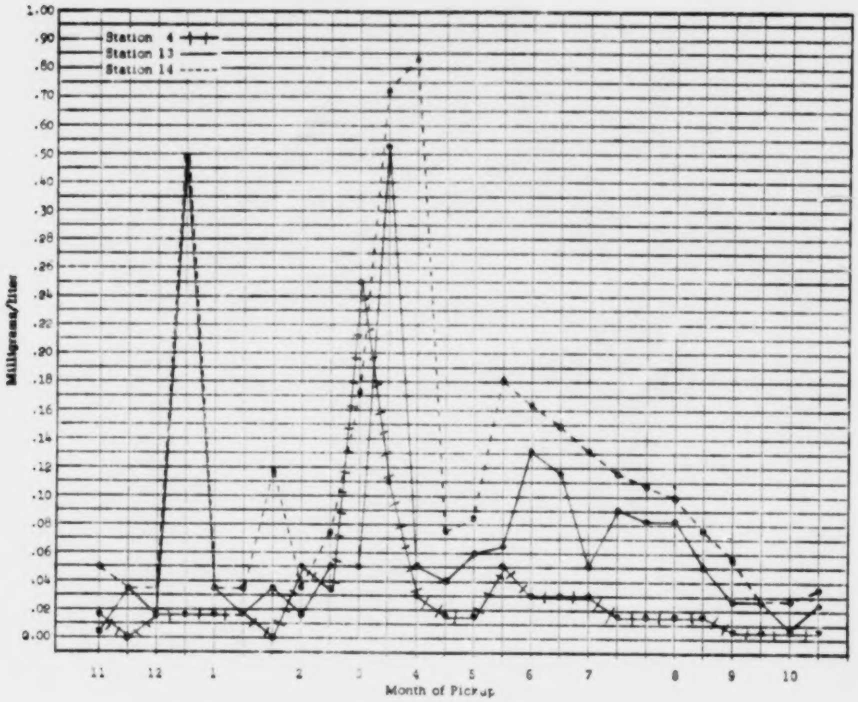

Figure 157. Springville Hatchery (Receiving water), Nitrite, Stations 4, 13 and 14.

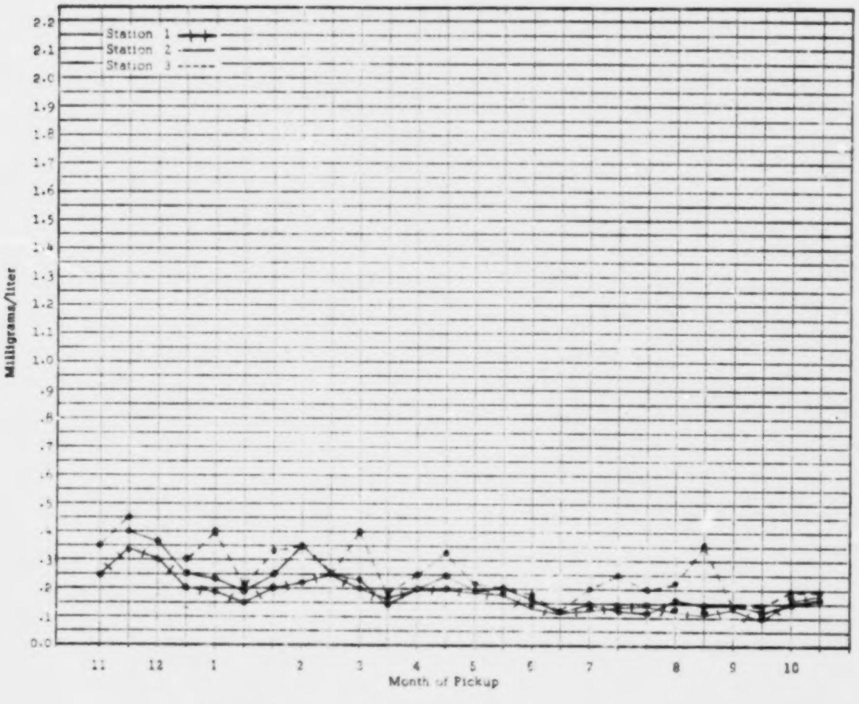

Figure 158. Springville Hatchery (State), Ammonia, Stations 1, 2 and 3.

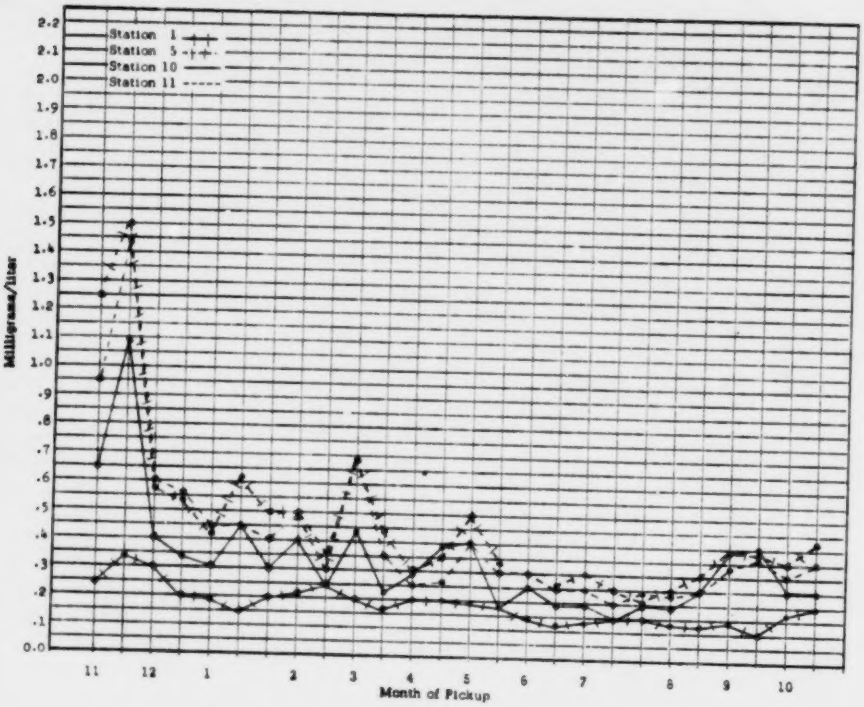

Figure 159. Springville Hatchery (Federal), Ammonia. Stations 1, 5, 10 and 11.

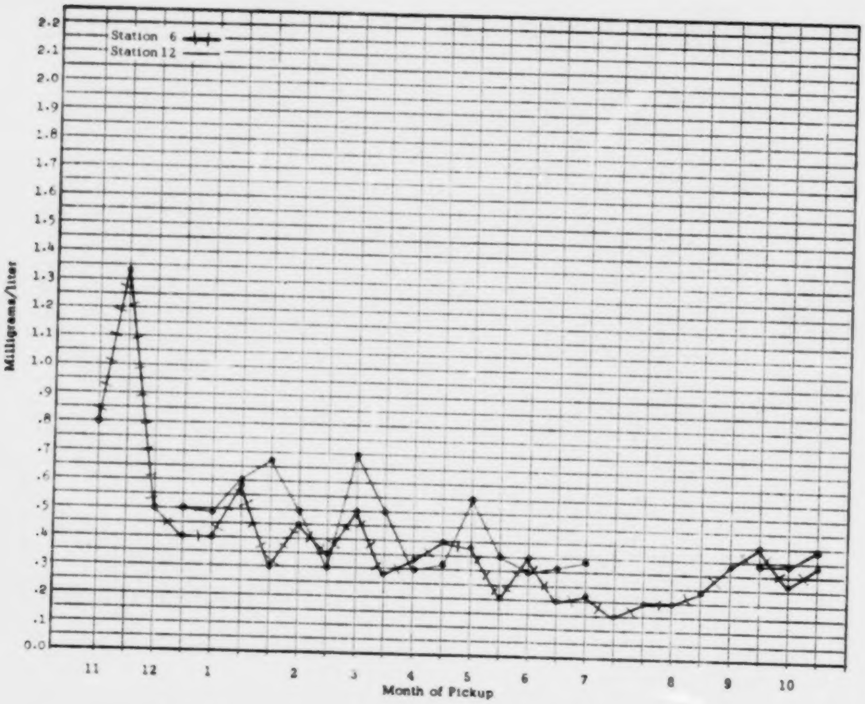

Figure 160. Springville Hatchery (Federal pond), Ammonia. Stations 6 and 12.

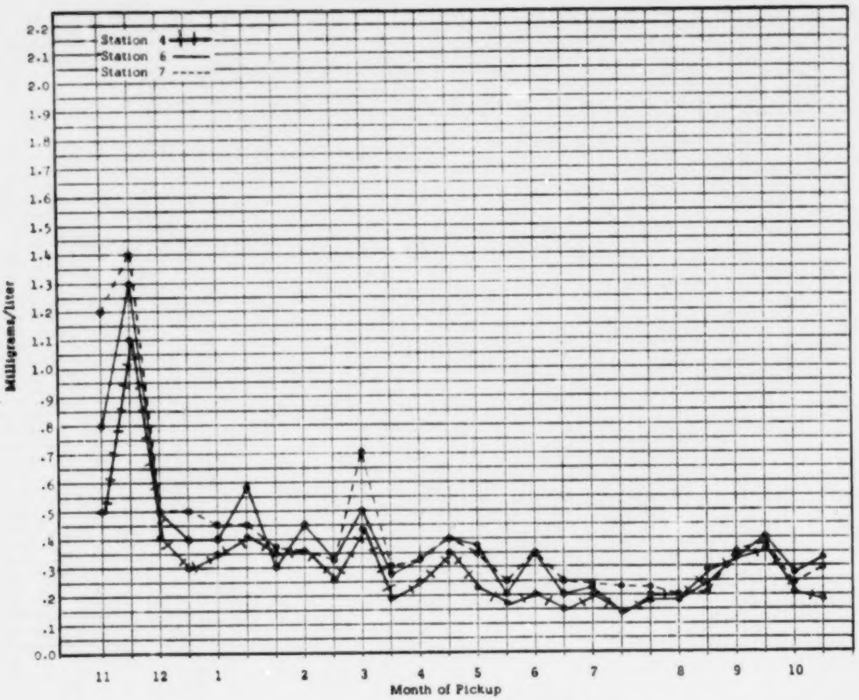

Figure 161. Springville Hatchery (Receiving water). Ammonia. Stations 4, 6 and 7.

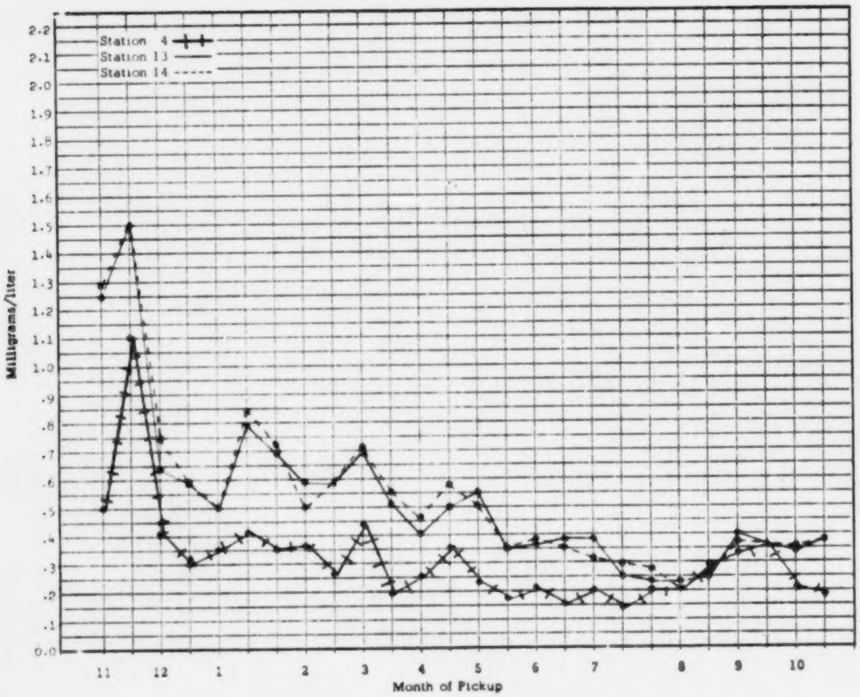

Figure 162. Springville Hatchery (Receiving water). Ammonia. Stations 4, 13 and 14.

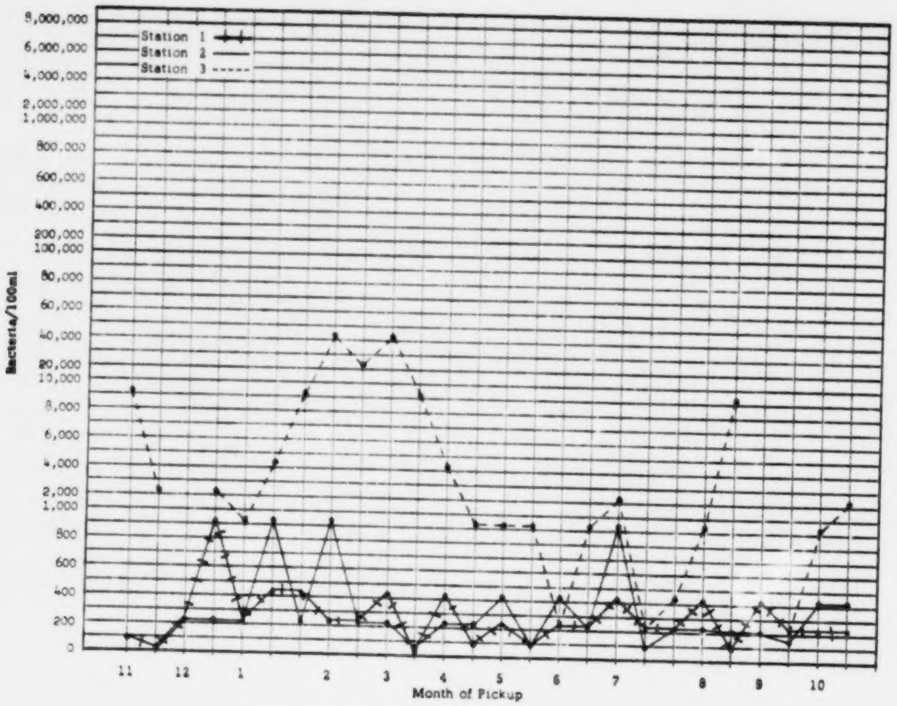

Figure 163. Springville Hatchery (State). M.P.N. Coliform. Stations 1, 2 and 3.

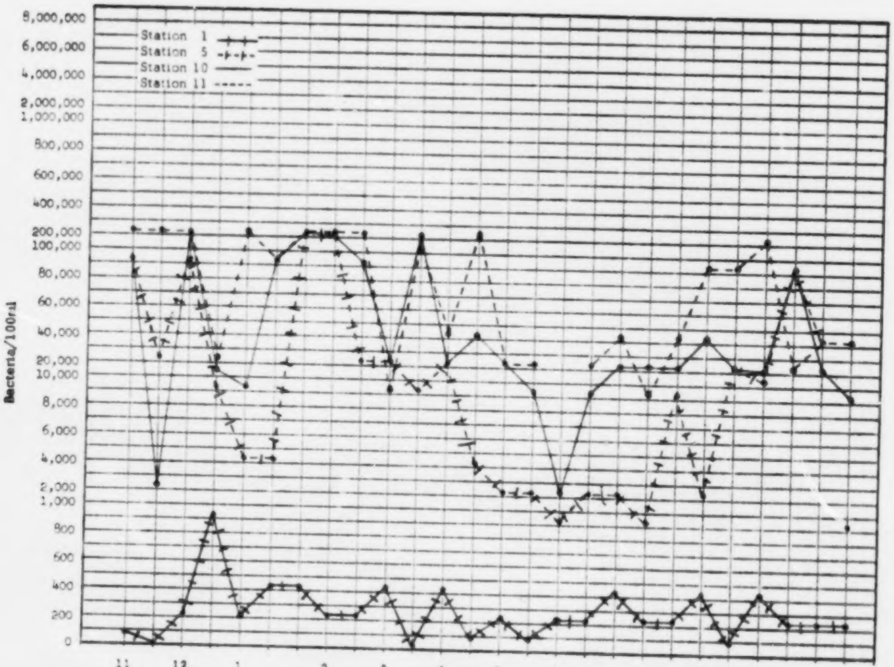

Figure 164. Springville Hatchery (Federal), M.P.N. Coliform. Stations 1, 5, 10 and 11.

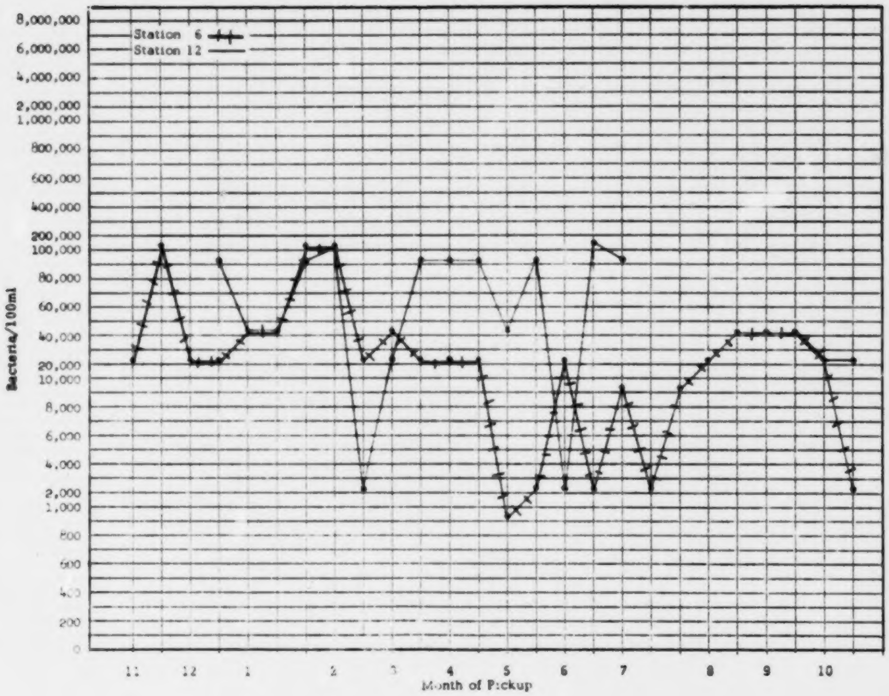

Figure 165. Springville Hatchery (Federal pond), M.F.N. Coliform. Stations 6 and 12.

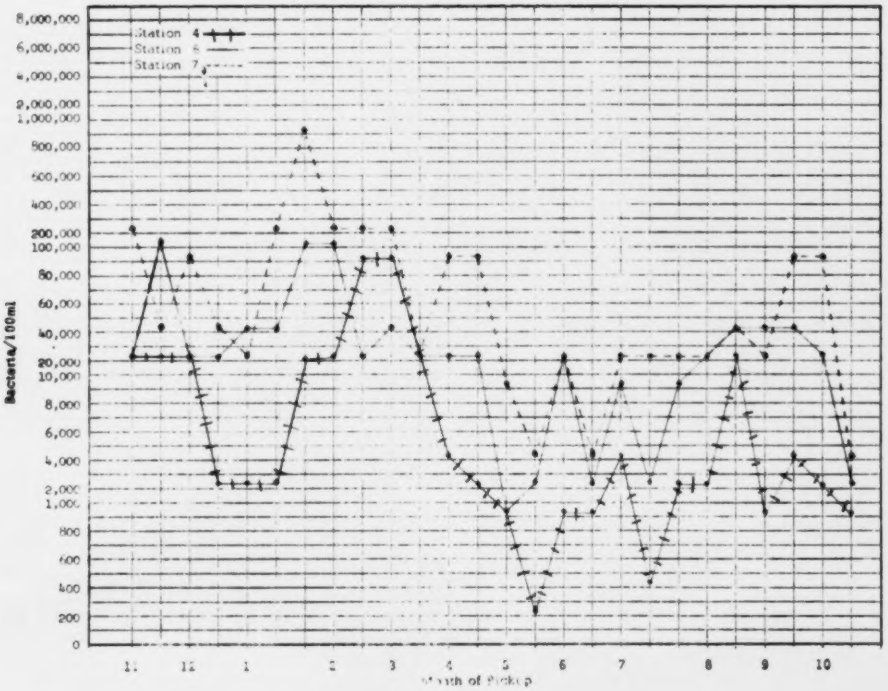

Figure 166. Springville Hatchery (Receiving water), M.F.N. Coliform. Stations 4, 6 and 7.

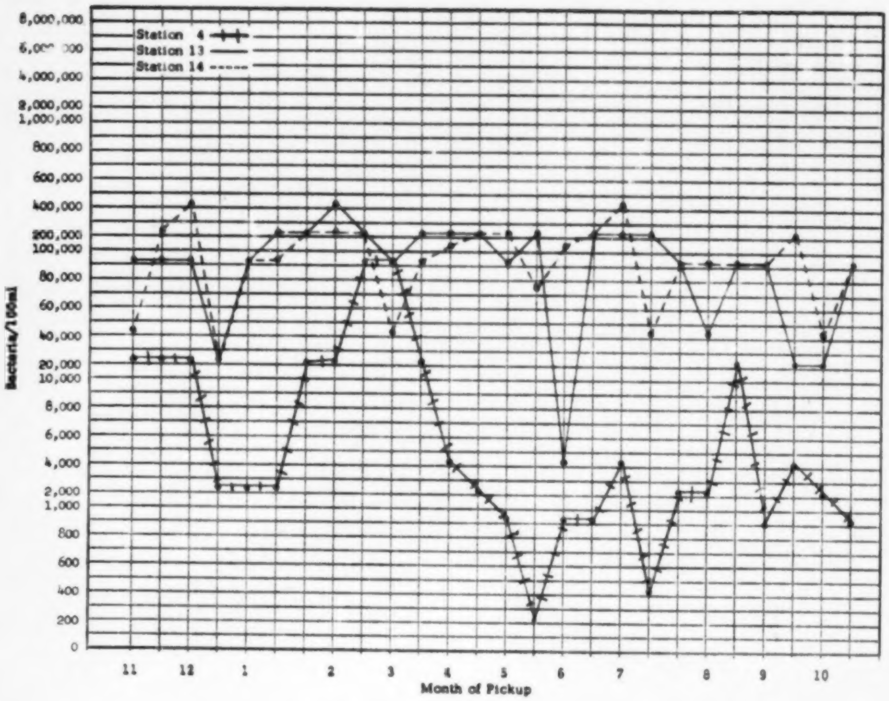

Figure 167. Springville Hatchery (Receiving water), M.P.N. Coliform. Stations 4, 13 and 14.

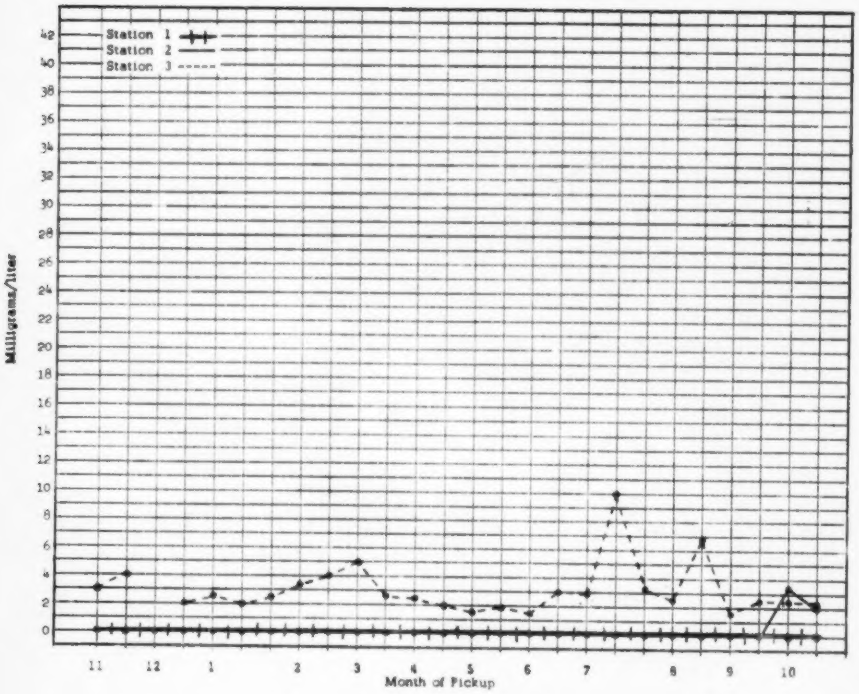

Figure 168. Springville Hatchery (State), Biochemical Oxygen Demand. Stations 1, 2 and 3.

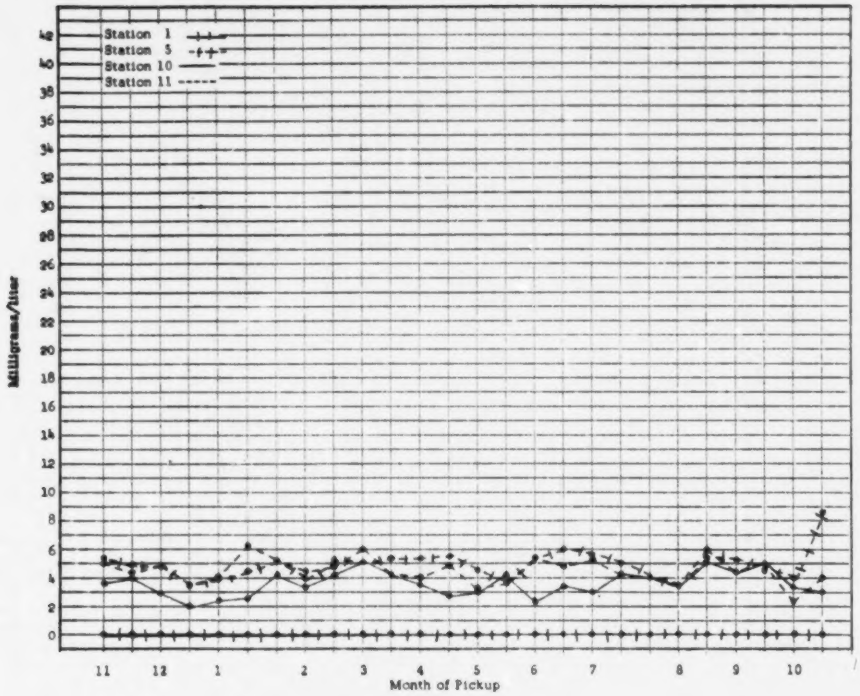

Figure 169. Springville Hatchery (Federal), Biochemical Oxygen Demand. Stations 1, 5, 10 and 11.

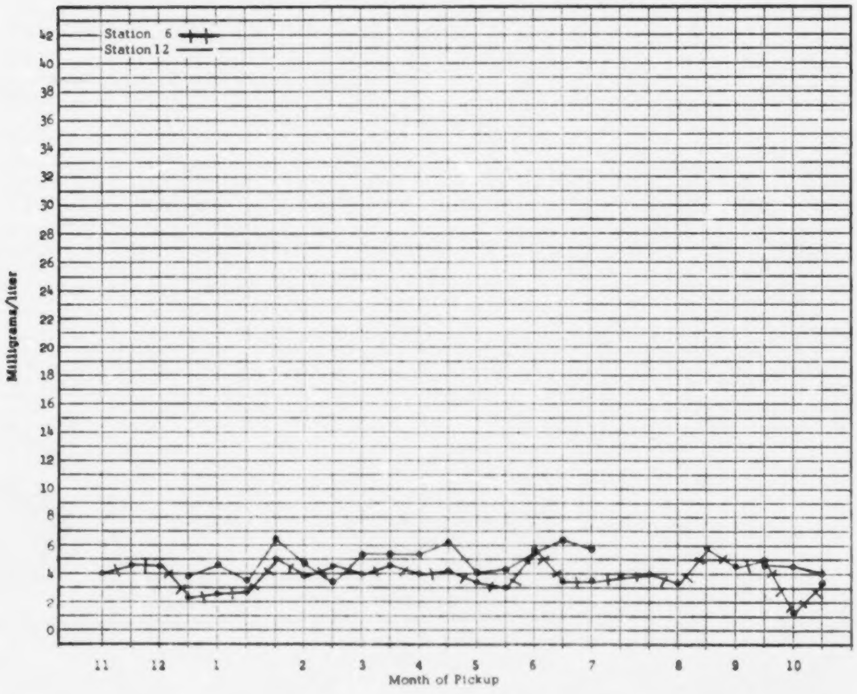

Figure 170. Springville Hatchery (Federal pond), Biochemical Oxygen Demand. Stations 6 and 12.

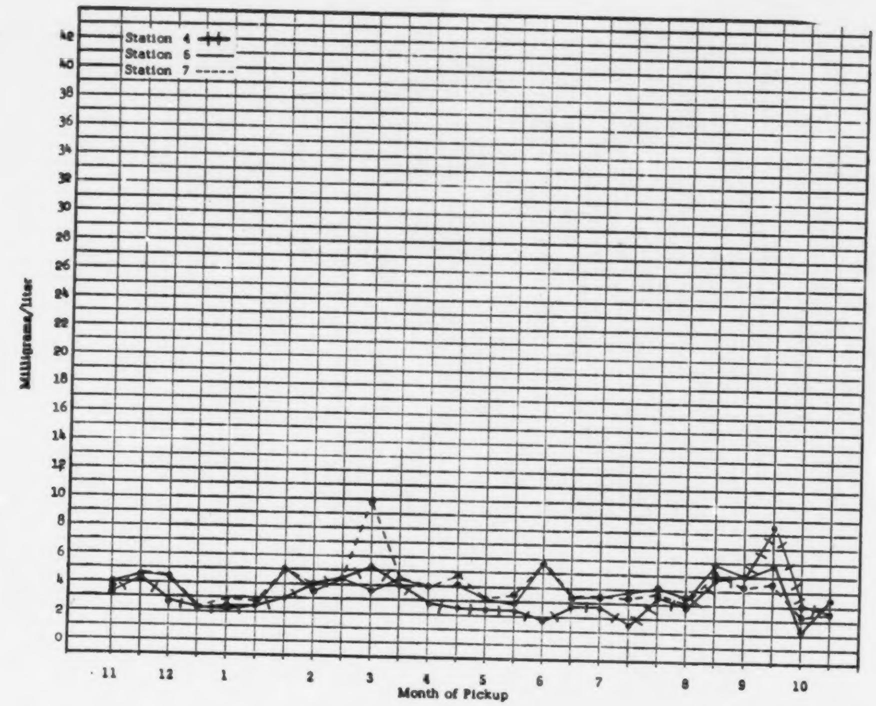

Figure 171. Springville Hatchery (Receiving water), Biochemical Oxygen Demand. Stations 4, 6 and 7.

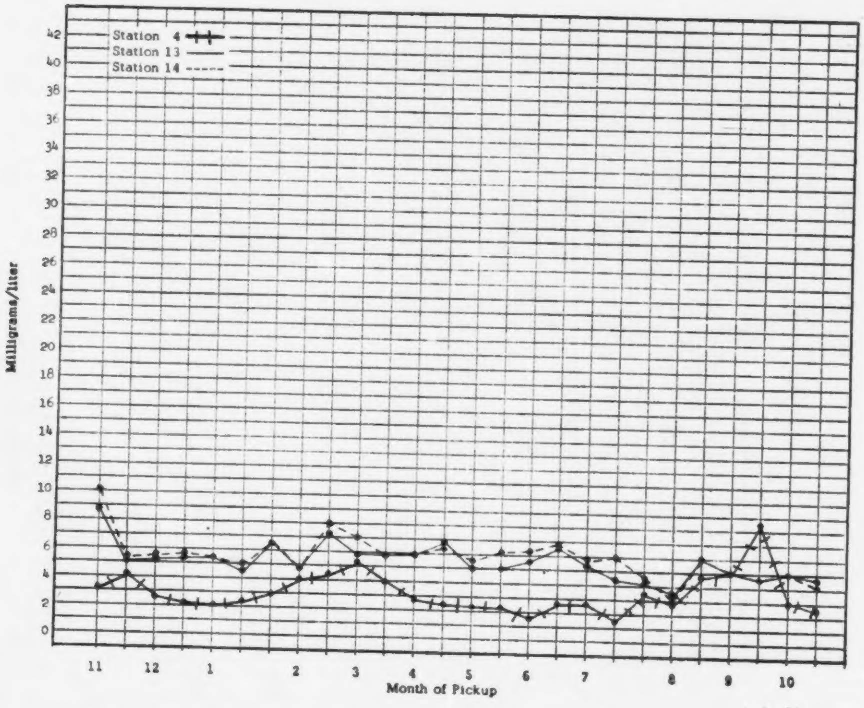

Figure 172. Springville Hatchery (Receiving water), Biochemical Oxygen Demand. Stations 4, 13 and14.

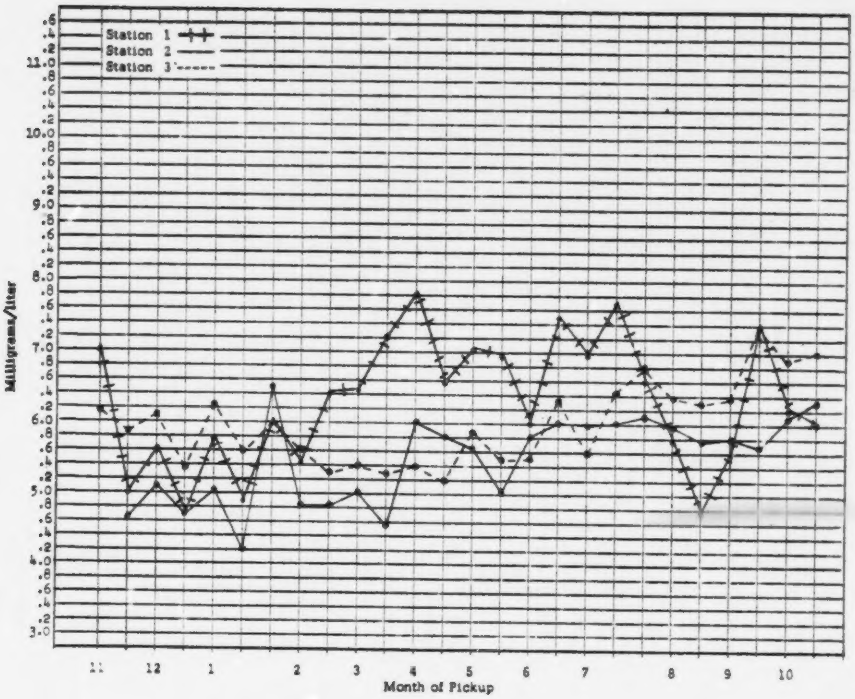

Figure 173. Springville Hatchery (State), Dissolved Oxygen. Stations 1, 2 and 3.

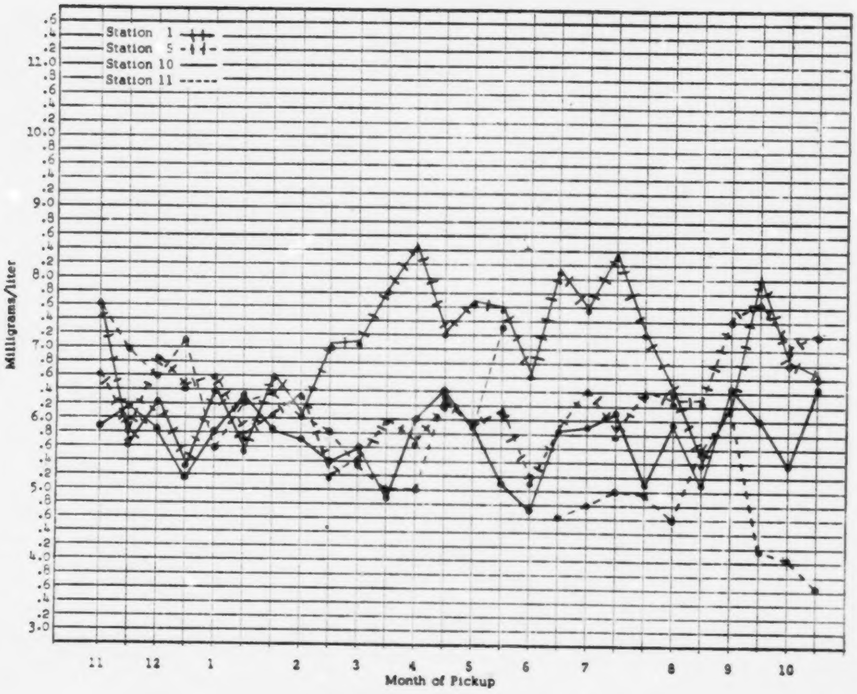

Figure 174. Springville Hatchery (Federal), Dissolved Oxygen. Stations 1, 5, 10 and 11.

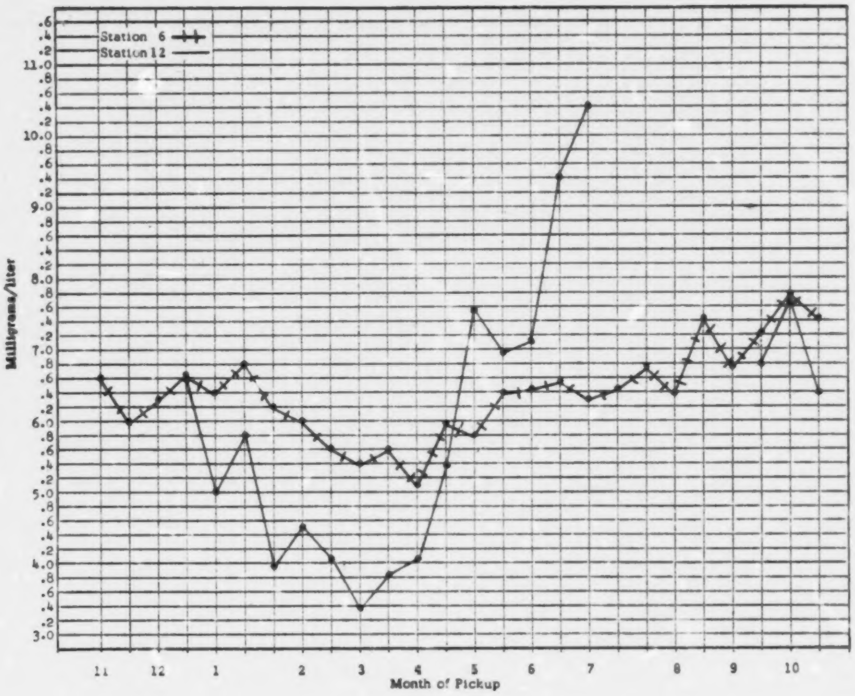

Figure 175. Springville Hatchery (Federal pond), Dissolved Oxygen. Stations 6 and 12.

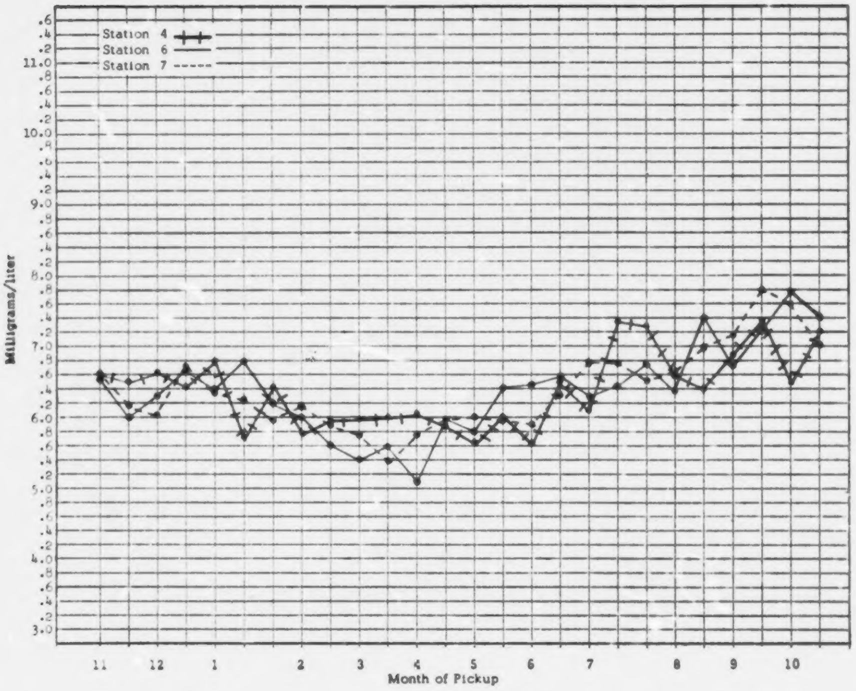

Figure 176. Springville Hatchery (Receiving water), Dissolved Oxygen. Stations 4, 6 and 7.

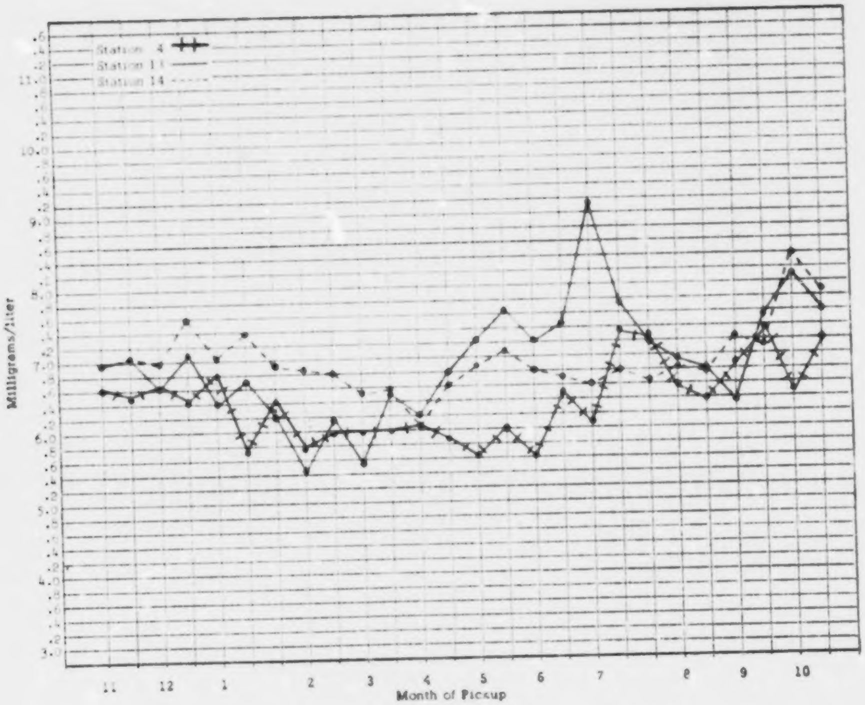

Figure 177. Springville Hatchery (Receiving water). Dissolved Oxygen. Stations 4, 13 and 14.

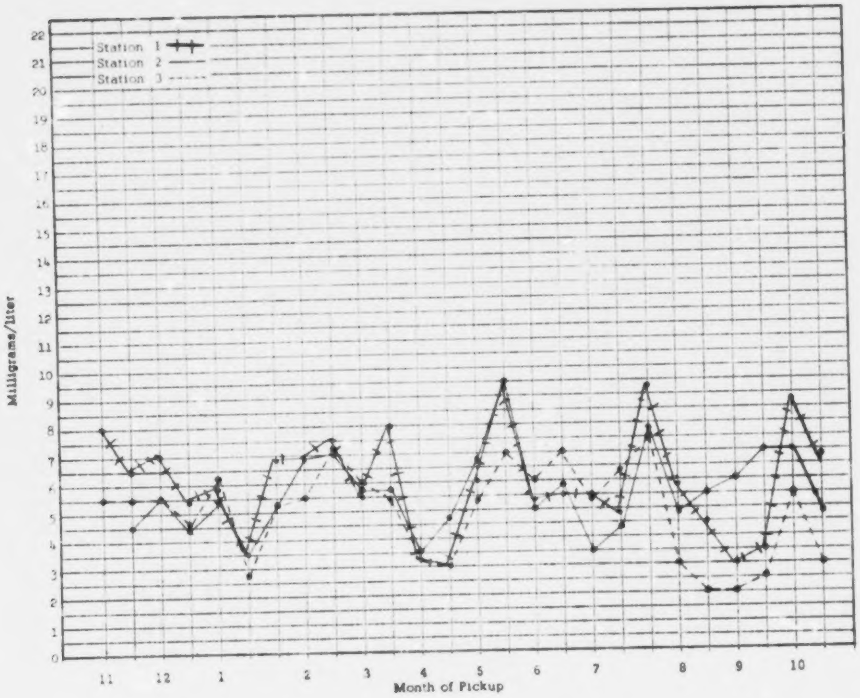

Figure 178. Springville Hatchery (State). Carbon Dioxide. Stations 1, 2 and 3.

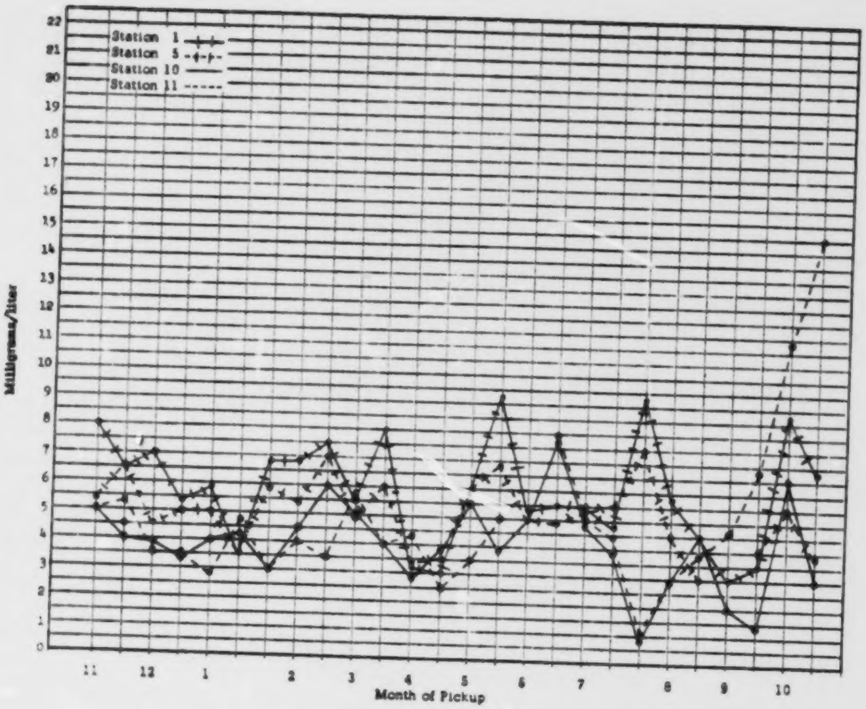

Figure 179. Springville Hatchery (Federal). Carbon Dioxide. Stations 1, 5, 10 and 11.

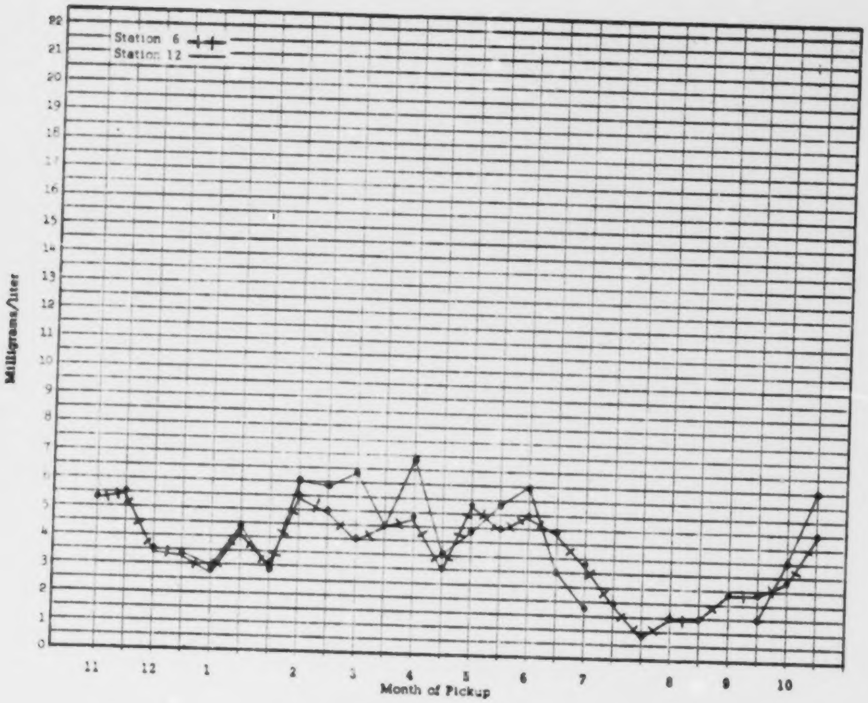

Figure 180. Springville Hatchery (Federal pond). Carbon Dioxide. Stations 6 and 12.

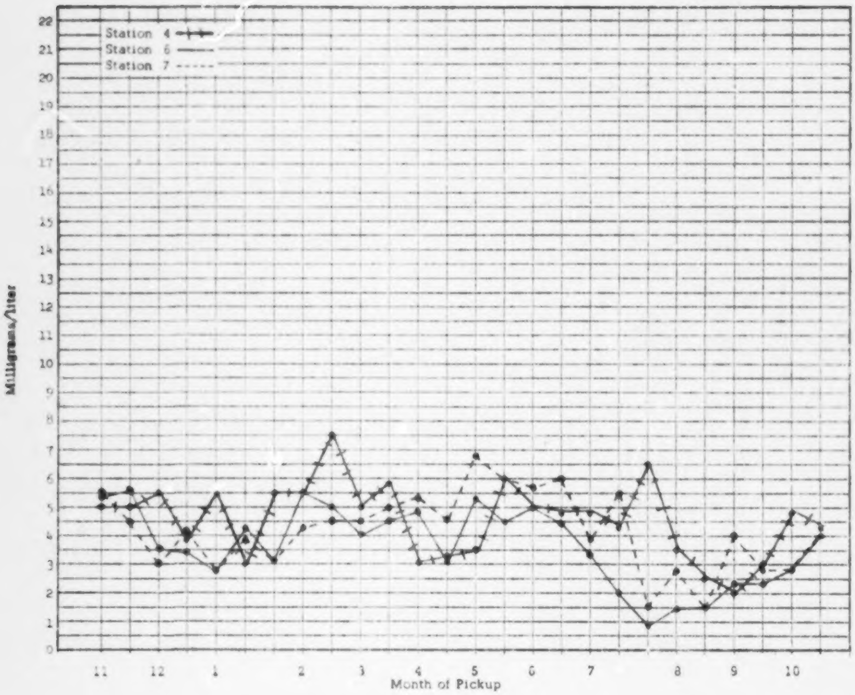

Figure 181. Springville Hatchery (Receiving water), Carbon Dioxide. Stations 4, 6 and 7.

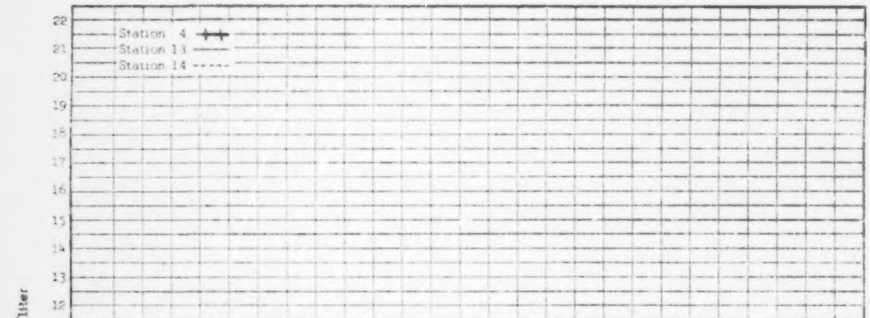

Figure 182. Springville Hatchery (Receiving water), Carbon Dioxide. Stations 4, 13 and 14.

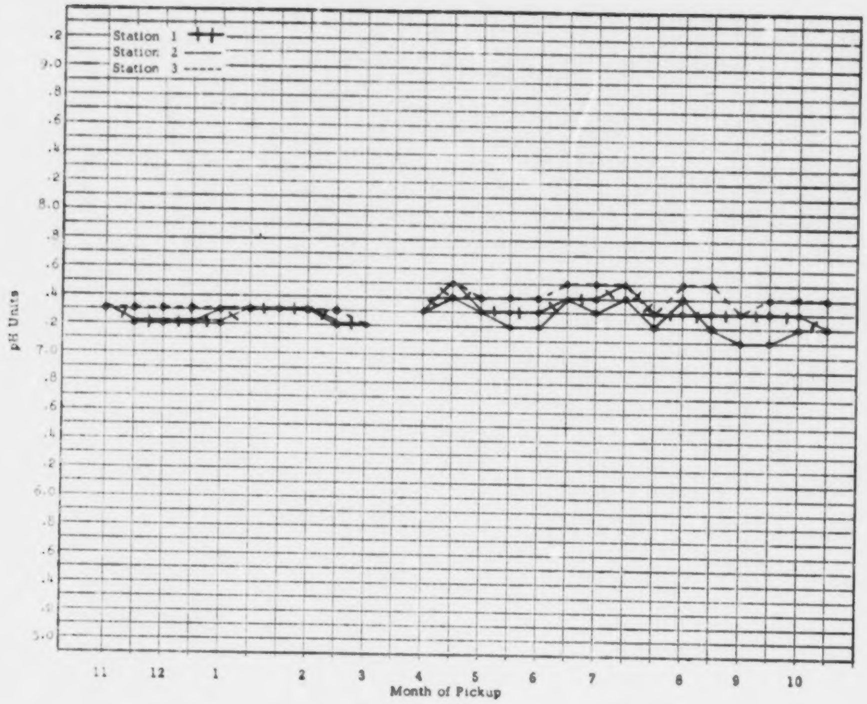

Figure 183. Springville Hatchery (State). Hydrogen Ion Concentration. Stations 1, 2 and 3.

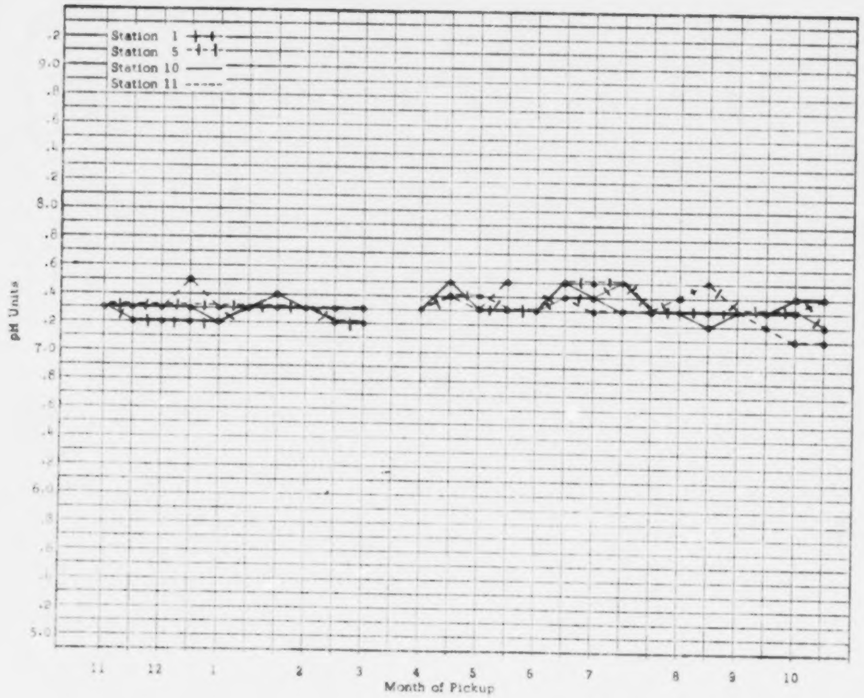

Figure 184. Springville Hatchery (Federal), Hydrogen Ion Concentration. Stations 1, 5, 10 and 11.

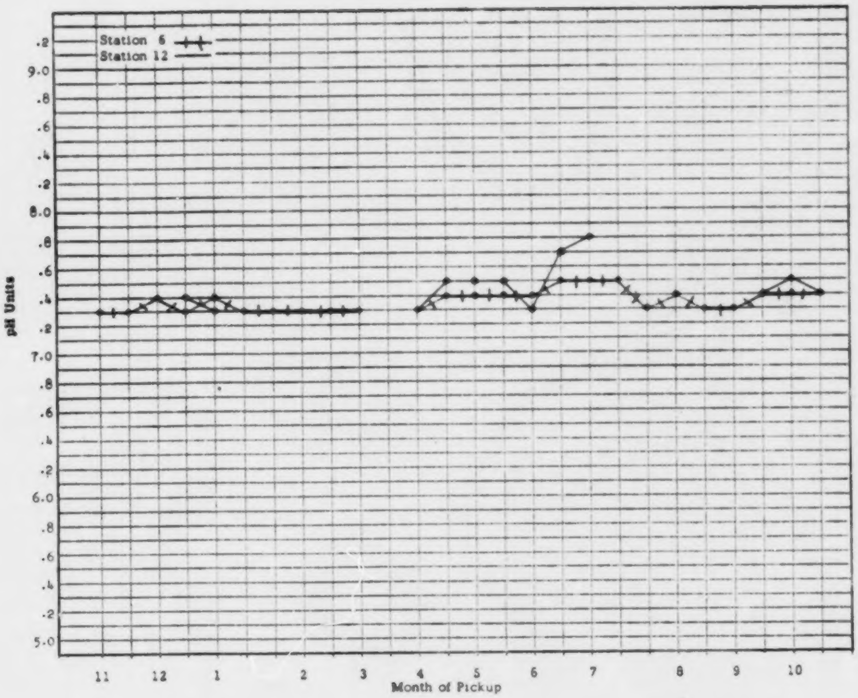

Figure 185. Springville Hatchery (Federal pond), Hydrogen Ion Concentration, Stations 6 and 12.

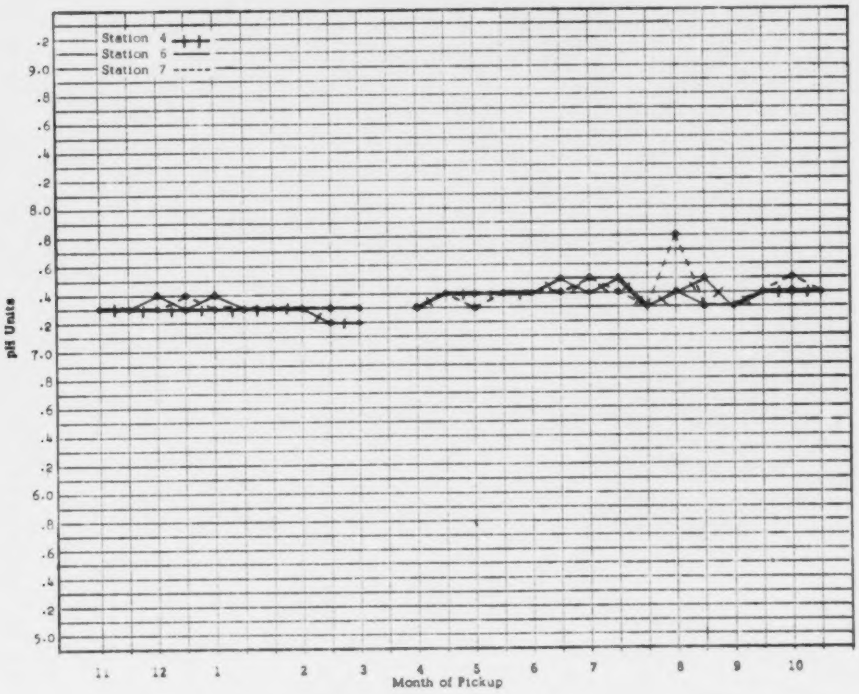

Figure 186. Springville Hatchery (Receiving water), Hydrogen Ion Concentration, Stations 4, 6 and 7.

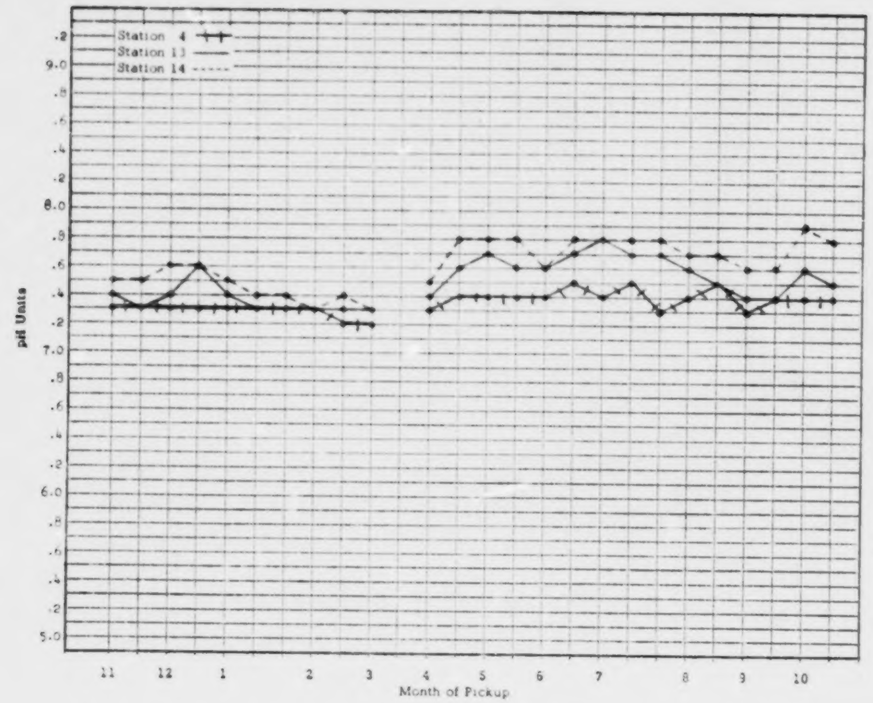

Figure 187. Springville Hatchery (Receiving water), Hydrogen Ion Concentration. Stations 4, 13 and 14.

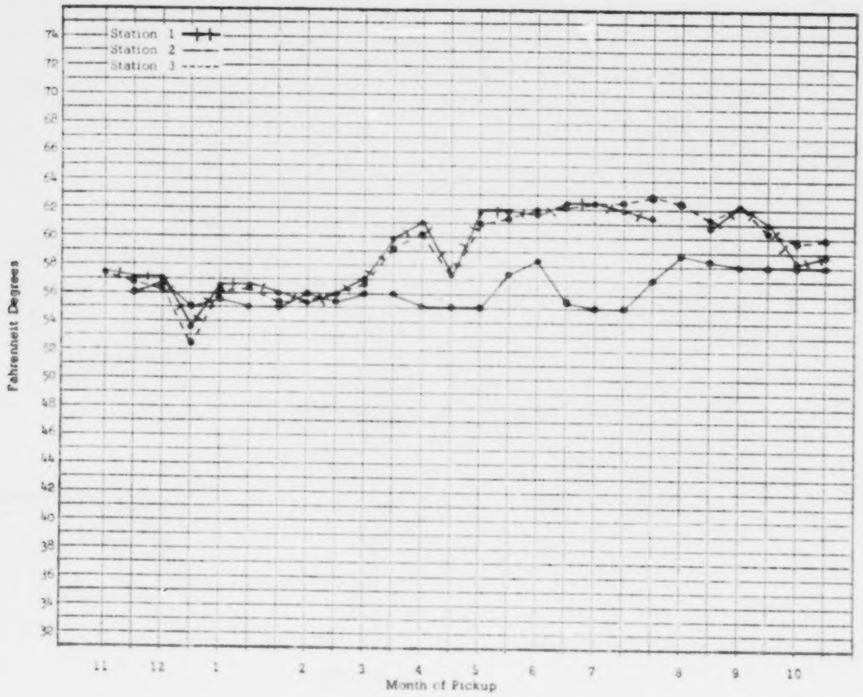

Figure 188. Springville Hatchery (State), Temperature. Stations 1, 2 and 3.

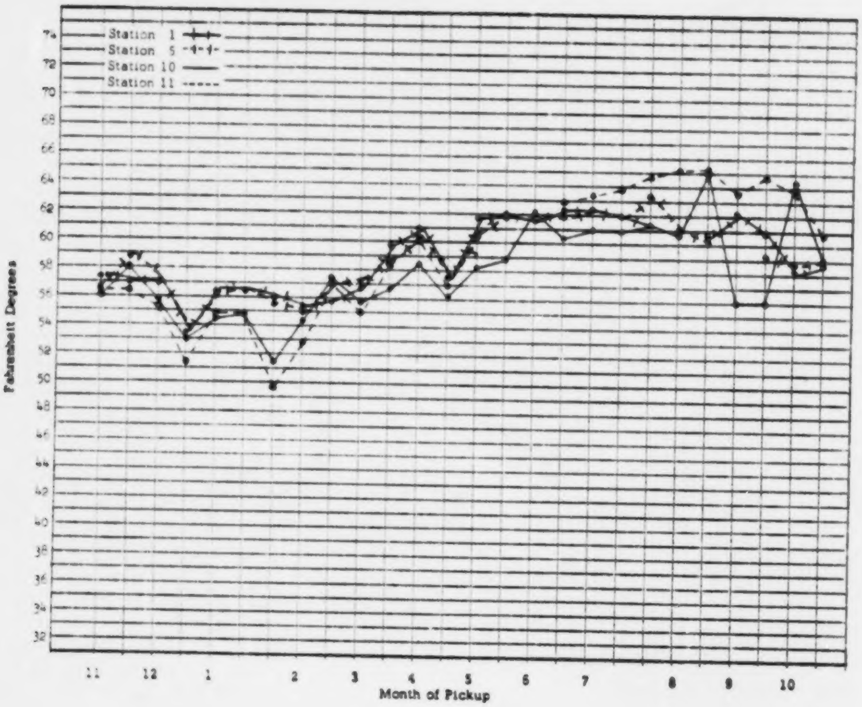

Figure 189. Springville Hatchery (Federal). Temperature. Stations 1, 5, 10 and 11.

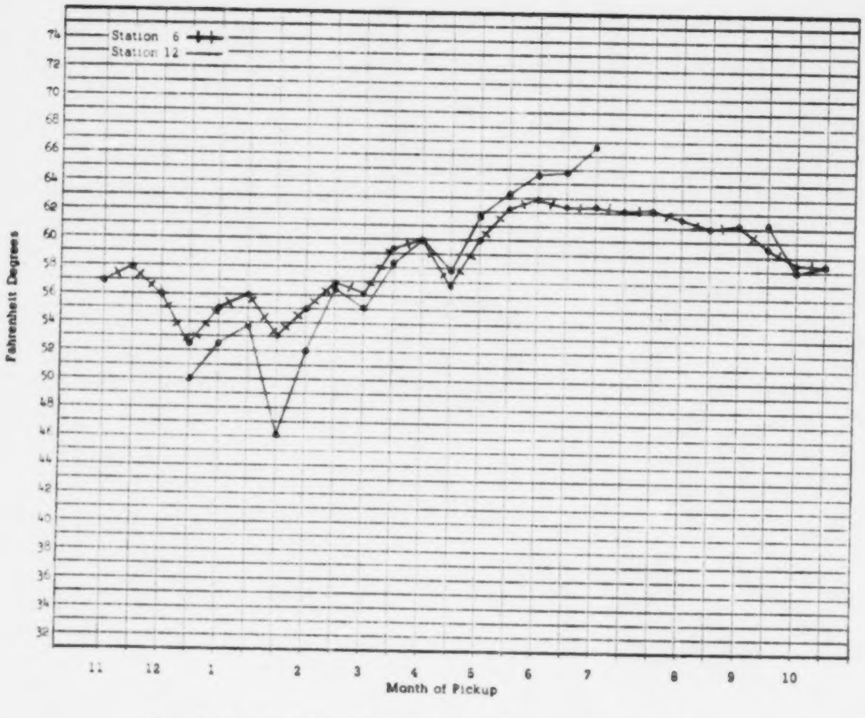

Figure 190. Springville Hatchery (Federal pond). Temperature. Stations 6 and 12.

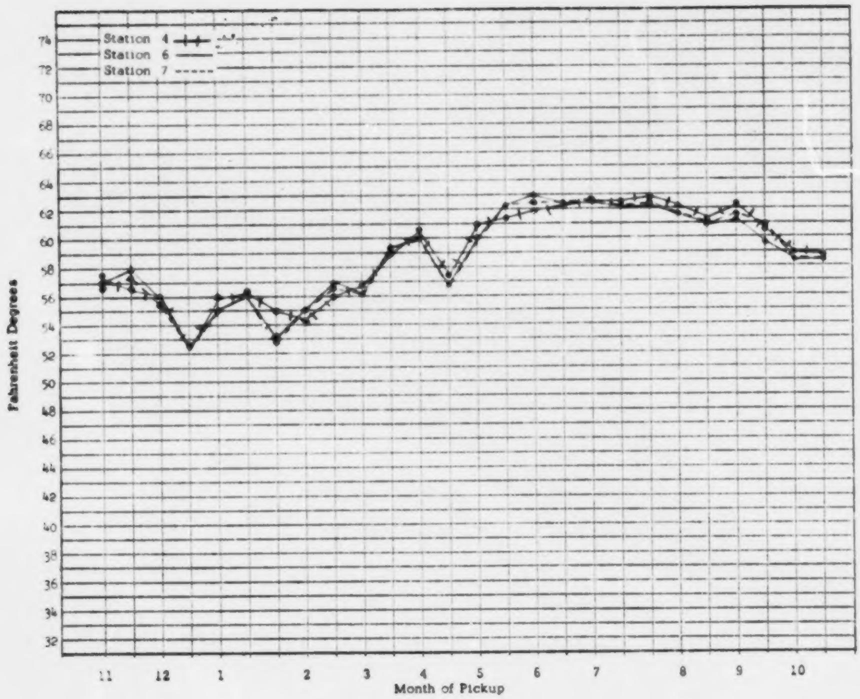

Figure 191. Springville Hatchery (Receiving water), Temperature. Stations 4, 6 and 7.

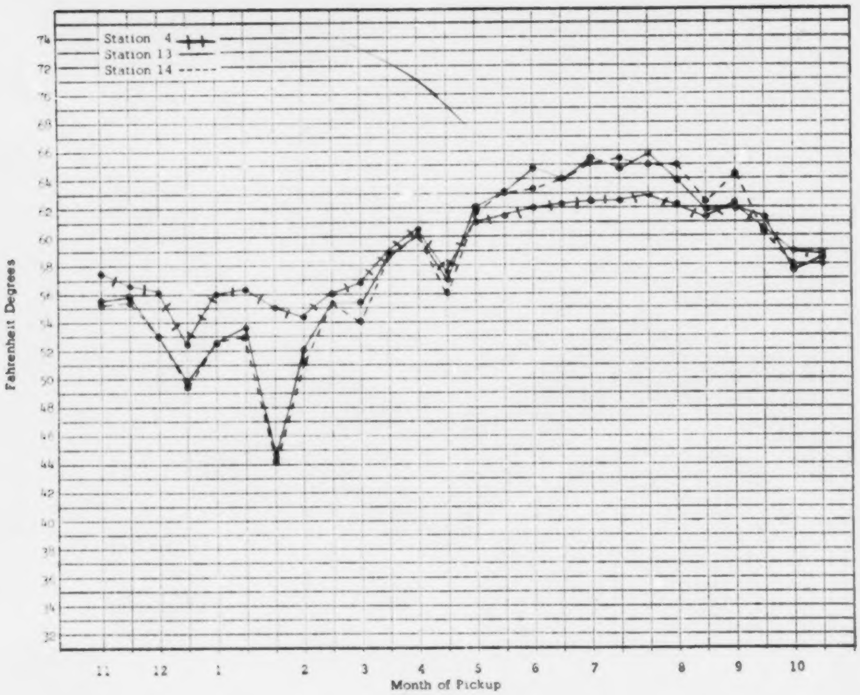

Figure 192. Springville Hatchery (Receiving water), Temperature. Stations 4, 13 and 14.

APPENDIX B

STATISTICAL ANALYSIS OF VARIANCE

TABLE 2. KAMAS HATCHERY RECEIVING WATER, STATISTICAL ANALYSIS OF VARIANCE

Parameter	Above (Station 4) Mean	Above (Station 4) Standard Deviation	Below (Station 6) Mean	Below (Station 6) Standard Deviation	T Value	Probability	F	Significance
M.O. Alkalinity	50.00	23.66	122.7	43.04	-7.546	.5215-07	3.308	**
Total Hardness	63.85	25.78	145.0	51.63	-7.170	.4470-07	4.011	**
Nitrates	1.192	2.599	1.565	2.498	-.5283	.2998	1.082	...
Nitrites	.4192-02	.7099-02	.1738-01	.2341-01	-2.750	.4137-02	10.87	**
Settleable Solids	.3769-01	.6629-01	.5885-01	.1496	-.6593	.2564	5.091	...
Sp. Conductance	142.7	41.45	285.6	89.09	-7.415	.5215-07	4.618	**
Turbidity	13.88	12.53	9.769	12.92	1.166	.8754	1.063	...
Ammonia	.2404	.1490	.3950	.2001	-3.160	.1340-02	1.803	**
B.O.D.	3.369	1.631	5.088	1.169	-4.369	.3157-04	1.944	**
M.P.N. Coliform	.6114+05	.1829+06	.9219+05	.7739+05	-.7974	.2145	5.584	...
Suspended Solids	4.415	7.039	6.900	7.334	-1.246	.1092	1.085	...
Total Dis. Solids	277.5	261.9	306.8	221.5	-.4362	.3323	1.397	...
Dissolved Oxygen	8.462	.9855	8.119	.6438	1.483	.9278	2.344	...
pH	7.123	1.233	7.250	1.260	-.3671	.3576	1.044	...
Carbon Dioxide	1.115	.5883	1.077	.2717	.3026	.6183	4.687	...
Temperature	42.72	11.16	48.25	6.198	-2.211	.1581-01	3.240	*

* Indicates significance at the 95% confidence interval.
**Indicates significance at the 99% confidence interval.

TABLE 3. MIDWAY HATCHERY RECEIVING WATER, STATISTICAL ANALYSIS OF VARIANCE

Parameter	Above (Station 4) Mean	Above (Station 4) Standard Deviation	Below (Station 6) Mean	Below (Station 6) Standard Deviation	T Value	Probability	F	Significance
M.O. Alkalinity	277.7	35.70	289.6	21.63	-1.457	.7575-01	2.724	...
Total Hardness	425.4	80.31	444.2	54.57	-.9897	.1635	2.166	...
Nitrates	2.635	2.319	3.151	1.806	-.8947	.1876	1.648	...
Nitrites	.1604-01	.1942-01	.2588-01	.9262-02	-2.334	.1183-01	4.395	*
Settleable Solids	.9538-01	.1047	.2962-01	.3092-01	3.071	.9983	11.48	**
Sp. Conductance	900.6	133.5	972.1	94.43	-2.231	.1510-01	1.998	*
Turbidity	14.23	14.31	6.577	6.351	2.493	.9920	5.078	*
Ammonia	.5081	.5824	.6027	.6321	-.5613	.2885	1.178	...
B.O.D.	4.912	4.381	5.708	4.625	-.6372	.2634	1.115	...
M.P.N. Coliform	.5396+05	.7090+05	.1973+06	.4375+06	-1.649	.5273-01	38.08	...
Suspended Solids	4.892	7.573	6.808	9.295	-.8146	.2096	1.506	...
Total Dis. Solids	670.6	74.97	674.8	49.01	-.2408	.4053	2.340	...
Dissolved Oxygen	7.954	.5736	8.246	.7295	-1.606	.5727-01	1.618	...
pH	7.816	.3300	7.360	.8167-01	6.707	1.0000	16.33	**
Carbon Dioxide	2.500	4.245	4.346	1.384	-2.108	.2002-01	9.408	*
Temperature	52.19	5.705	54.35	5.327	-1.412	.8207-01	1.147	...

* Indicates significance at the 95% confidence interval.
**Indicates significance at the 99% confidence interval.

TABLE 4. LOA HATCHERY RECEIVING WATER, STATISTICAL ANALYSIS OF VARIANCE

Parameter	Above (Station 1) Mean	Above (Station 1) Standard Deviation	Below (Station 4) Mean	Below (Station 4) Standard Deviation	T Value	Probability	F	Significance
M.O. Alkalinity	99.23	6.884	101.6	23.78	-.4832	.3155	11.93	...
Total Hardness	105.8	16.53	108.2	29.65	-.3582	.3609	3.215	...
Nitrates	1.766	1.729	1.889	1.719	-.2582	.3987	1.012	...
Nitrites	.4000-02	.5521-02	.2381-01	.2099-01	-4.654	.1219-04	14.45	**
Settleable Solids	.1000-01	.2413-05	.5808-01	.9724-01	-2.521	.7469-02	.1625+10	*
Sp. Conductance	261.3	23.98	271.2	58.81	-.7905	.2165	6.014	...
Turbidity	2.000	2.263	3.000	2.498	-1.513	.6831-01	1.219	...
Ammonia	.2062	.8295-01	.4831	.3605	-3.817	.1865-03	18.89	**
B.O.D.	.6038	.2973	5.477	2.252	-10.94	.2980-07	57.37	**
M.P.N. Coliform	2676.	6176.	.7535+05	.9996+05	-3.700	.2683-03	262.0	**
Suspended Solids	.5538	.1985	5.773	4.457	-5.965	.1863-06	504.4	**
Total Dis. Solids	190.6	49.83	200.2	54.42	-.6645	.2547	1.193	...
Dissolved Oxygen	6.954	.1703	6.692	.3610	3.341	.9992	4.496	**
pH	7.820	.1444	7.684	.2055	2.708	.9953	2.027	**
Carbon Dioxide	.3846-01	.1961	.5000	.8124	-2.816	.3471-02	17.16	**
Temperature	60.12	.3258	60.08	2.201	.7053-01	.5280	45.61	...

* Indicates significance at the 95% confidence interval.
**Indicates significance at the 99% confidence interval.

TABLE 5. WHITE HATCHERY RECEIVING WATER, STATISTICAL ANALYSIS OF VARIANCE

Parameter	Above (Station 5) Mean	Above (Station 5) Standard Deviation	Below (Station 9) Mean	Below (Station 9) Standard Deviation	T Value	Probability	F	Significance
M.O. Alkalinity	220.8	49.57	218.8	47.03	.1484	.5587	1.111	...
Total Hardness	241.6	52.81	238.3	47.97	.2263	.5890	1.212	...
Nitrates	1.824	1.878	2.578	1.987	-1.366	.8922-01	1.120	...
Nitrites	.3880-01	.5624-01	.3050-01	.3448-01	.6196	.7307	2.661	...
Settleable Solids	.3020	.9950	.3478	.7273	-.1808	.4287	1.872	...
Sp. Conductance	460.4	101.7	457.1	95.67	.1175	.5465	1.130	...
Turbidity	101.1	359.0	76.17	217.1	.2929	.6145	2.735	...
Ammonia	.3500	.1793	.6017	.3160	-3.447	.6026-03	3.105	**
B.O.D.	3.945	1.233	7.600	5.017	-3.531	.4692-03	16.55	**
M.P.N. Coliform	.7160+05	.8616+05	.3911+06	.5076+06	-3.102	.1623-02	34.72	**
Suspended Solids	28.68	92.20	56.39	145.7	-.7990	.2142	2.497	...
Total Dis. Solids	304.2	52.25	320.2	50.11	-1.097	.1392	1.087	...
Dissolved Oxygen	9.272	.8259	8.200	1.306	3.449	.9994	2.501	**
pH	7.504	1.934	7.333	1.926	.3094	.6208	1.008	...
Carbon Dioxide	.0000	.0000	.4167	.7173	-2.906	.2785-02	.0000	**
Temperature	49.16	10.49	47.51	8.540	.6029	.7253	1.509	...

* Indicates significance at the 95% confidence interval.
**Indicates significance at the 99% confidence interval.

TABLE 6. STATE HATCHERY AT SPRINGVILLE RECEIVING WATER, STATISTICAL ANALYSIS OF VARIANCE

Parameter	Above (Station 1) Mean	Above (Station 1) Standard Deviation	Below (Station 4) Mean	Below (Station 4) Standard Deviation	T Value	Probability	F	Significance
M.O. Alkalinity	235.4	7.606	235.8	8.567	-.1712	.4324	1.269	...
Total Hardness	481.9	51.69	493.1	44.70	-.8322	.2046	1.337	...
Nitrates	2.839	1.596	2.578	.6151	.7773	.7797	6.735	...
Nitrites	.1027-01	.8229-02	.3092-01	.4988-01	-2.083	.2119-01	36.74	*
Settleable Solids	.1000-01	.2413-05	.3385-01	.9696-01	-1.254	.1078	.1615+10	...
Sp. Conductance	967.9	31.57	999.9	29.16	-3.802	.1958-03	1.172	**
Turbidity	1.962	1.865	4.154	6.386	-1.680	.4956-01	11.72	...
Ammonia	.1819	.5470-01	.3135	.1884	-3.418	.6304-03	11.87	**
B.O.D.	.5000	.0000	3.365	1.479	-9.881	.3725-07	.0000	**
M.P.N. Coliform	292.6	226.5	.1459+05	.2488+05	-2.930	.2550-02	.1206+05	**
Suspended Solids	.5000	.0000	2.612	1.084	-9.931	.4470-07	.0000	**
Total Dis. Solids	615.7	69.33	641.9	82.70	-1.239	.1105	1.423	...
Dissolved Oxygen	6.850	.9105	6.419	.5307	2.084	.9789	2.944	*
pH	7.062	1.219	7.112	1.229	-.1473	.4417	1.017	...
Carbon Dioxide	6.115	1.818	4.731	1.430	3.052	.9982	1.617	**
Temperature	57.71	7.096	58.96	3.060	-.8248	.2067	5.378	...

* Indicates significance at the 95% confidence interval.
**Indicates significance at the 99% confidence interval.

TABLE 7. FEDERAL HATCHERY AT SPRINGVILLE - #1, IRONTON CANAL STATISTICAL ANALYSIS OF VARIANCE

	Above (Station 4)		Below (Station 7)					
Parameter	Mean	Standard Deviation	Mean	Standard Deviation	T Value	Probability	F	Significance
M.O. Alkalinity	255.4	7.606	262.1	132.9	-1.022	.1557	305.1	...
Total Hardness	481.9	51.69	470.3	104.9	.5104	.6940	4.116	...
Nitrates	2.839	1.596	2.411	.5629	1.284	.8975	5.799	...
Nitrites	.1027-01	.8229-02	.4456-01	.1314	-1.327	.9514-01	255.0	...
Settleable Solids	.1000-01	.2413-05	.1519-01	.2694-01	-.9810	.1656	.1247+09	...
Sp. Conductance	967.9	31.57	982.3	93.21	-.7441	.2301	8.719	...
Turbidity	1.962	1.865	3.667	3.893	-2.021	.2428-01	4.356	*
Ammonia	.1819	.5470-01	.4174	.2829	-4.169	.5940-04	26.74	**
B.O.D.	.5000	.0000	4.196	1.464	-12.87	.2980-07	.0000	**
M.P.N. Coliform	292.6	226.5	.1093+06	.1827+06	-3.041	.1860-02	.6507+06	**
Suspended Solids	.5000	.0000	4.841	4.493	-4.925	.4701-05	.0000	**
Total Dis. Solids	615.7	69.33	644.1	101.7	-1.184	.1209	2.152	...
Dissolved Oxygen	6.850	.9105	6.411	.5693	2.113	.9802	2.558	*
pH	7.062	1.219	7.152	1.216	-.2701	.3941	1.005	...
Carbon Dioxide	6.115	1.818	4.185	1.570	4.142	.9999	1.342	**
Temperature	57.71	7.096	58.80	3.140	-.7243	.2361	5.106	...

* Indicates significance at the 95% confidence interval.
**Indicates significance at the 99% confidence interval.

TABLE 8. FEDERAL HATCHERY AT SPRINGVILLE - #2, SPRING CREEK STATISTICAL ANALYSIS OF VARIANCE

Parameter	Above (Station 4) Mean	Above (Station 4) Standard Deviation	Below (Station 14) Mean	Below (Station 14) Standard Deviation	T Value	Probability	F	Significance
M.O. Alkalinity	235.4	7.606	257.7	158.0	-.7178	.2381	431.6	...
Total Hardness	481.9	51.69	503.4	158.5	-.6565	.2573	9.398	...
Nitrates	2.839	1.596	2.312	.6608	1.555	.9369	5.835	...
Nitrites	.1027-01	.8229-02	.1507	.2093	-3.417	.6334-03	647.0	**
Settleable Solids	.1000-01	.2413-05	.4308-01	.5160-01	-3.269	.9787-03	.4574+09	**
Sp. Conductance	967.9	31.57	951.8	197.1	.4116	.6588	38.99	...
Turbidity	1.962	1.865	4.462	3.776	-3.027	.1950-02	4.099	**
Ammonia	.1819	.5470-01	.5381	.3013	-5.930	.1863-06	30.34	**
B.O.D.	.5000	.0000	5.735	1.344	-19.86	.2235-07	.0000	**
M.P.N. Coliform	292.6	226.5	.1544+06	.1097+06	-7.160	.5960-07	.2347+06	**
Suspended Solids	.5000	.0000	7.569	6.853	-5.260	.1550-05	.0000	**
Total Dis. Solids	615.7	69.33	670.0	82.46	-2.572	.6562-02	1.415	*
Dissolved Oxygen	6.850	.9105	6.996	.4626	-.7297	.2345	3.874	...
pH	7.062	1.219	7.369	1.291	-.8840	.1905	1.122	...
Carbon Dioxide	6.115	1.818	2.077	1.055	9.795	1.0000	2.968	**
Temperature	57.71	7.096	58.26	5.677	-.3086	.3795	1.562	...

* Indicates significance at the 95% confidence interval.
**Indicates significance at the 99% confidence interval.

APPENDIX C

BOTTOM FAUNA DATA

TABLE 9. KAMAS HATCHERY BOTTOM FAUNA ANALYSIS, STATION 4.

Organism	4-4-69	5-2-69	6-16-69	7-25-69	8-21-69	9-18-69	11-12-69	1-19-70	3-27-70
Annelida									
Hirudinea	98	...	...	...	1	...	2	5	1
Oligochaete	10	1	...	...	...	...	...	1	...
Tubifex	78	...	...	...	40	...	...	3	2
Crustacea									
Amphipoda	12	5	...	...	...	...	...	...	...
Mollusca									
Gastropoda	7	...	...	...	...	1	...	...	1
Pelecypoda	87	...	1	...	...	...	2	1	...
Ephemeroptera									
Ameletus	...	...	...	4	6	...	5	8	34
Baetis	34	4	34	48	6	...	...	3	2
Cinygmula	...	...	21	...	...	...	...	...	...
Epeorus	...	...	21	12	...	...	...	...	...
Ephemerella	176	23	81	30	20	...	13	282	69
Heptagenia	...	...	...	...	16	...	...	...	20
Leptophlebia	...	...	...	...	...	...	10	12	22
Rhithrogena	...	28	10	12	...	...	...	59	45
Plecoptera									
Acroneuria	...	...	...	...	...	...	...	2	...
Alloperla	...	...	...	1	...	...	...	...	...
Arcynopteryx	...	...	...	...	...	...	...	...	1
Capnia	...	...	...	...	...	...	...	10	2
Claassenia	...	2	4	2	...	2	3	3	17
Isoperla	7	...	...	...	1	...	9	4	1
Nemoura	...	...	...	...	...	1	...	4	...
Pteronarcella	15	13	...	3	3	...	...	21	21

TABLE 9. KAMAS HATCHERY BOTTOM FAUNA ANALYSIS, STATION 4. (Cont'd.)

Organism	4-4-69	5-2-69	6-16-69	7-25-69	8-21-69	9-18-69	11-12-69	1-19-70	3-27-70
Coleoptera									
Dytiscidae	...	...	1	11	1	...	...	1	...
Elmidae	5	...	...	37	18	...	24	80	197
Halipidae	1	...	...	...	...	...	...	...	...
Diptera									
Antocha	14	...	...	...	...	...	...	...	...
Athrix	13	17	12	6	13	1	1	5	12
Chironomidae	483	...	...	2	12	...	1	3	5
Hexatoma	...	...	2	4	1	...	...	4	6
Limnophora	2	...	...	...	...	...	1	1	...
Muscidae	...	...	...	...	...	...	...	1	2
Raphidolabis	...	...	...	3	1	...	...	...	...
Simulidae	2	...	1	...	...	1	...	...	...
Stratiomyidae	...	1	...	...	...	...	...	38	62
Tipulidae	1	1	1	2	...	3	...	...	...
Trichoptera									
Arctopsyche	55	...	...	2	4	...	...	8	2
Brachycentrus	23	...	1	4	4	...	...	3	1
Glossosoma	...	1	...	...	...	...	...	...	...
Hydropsyche	194	...	10	...	2	...	2	65	68
Leptocella	72	1	15	11	6	...	145	728	396
Limnephilus	4	14	34	11	5	...	4	1	9
Rhyacophila	2	...	...	...	...	...	...	1	1
Total Org./sq. ft.	139.5	11.1	24.9	20.9	32.0	1.8	44.4	271.4	199.8
Kinds of Organisms	24	13	16	19	19	6	14	29	26

TABLE 10. KAMAS HATCHERY BOTTOM FAUNA ANALYSIS, STATION 5.

Organism	4-4-69	5-2-69	6-16-69	7-25-69	8-21-69	9-10-69	11-12-69	1-19-70	3-27-70
Annelida									
Hirudinea	3	185	140	57	179	182	100	515	194
Oligochaete	1	...	1	...	...	...	...	...	...
Tubifex	...	80	130	35	2	20	119	27	80
Crustacea									
Isopoda	...	...	...	...	...	1	1	...	...
Mollusca									
Gastropoda	...	2	19	4	16	13	33	23	2
Pelecypoda	...	32	9	...	...	...	4	5	...
Ephemeroptera									
Ameletus	...	...	3	...	...	...	...	...	1
Baetis	...	2	113	201	42	24	32	286	109
Cinygmula	6	...	15	...	...	...	...	...	...
Epeorus	...	...	2	9	...	...	...	...	4
Ephemerella	16	13	80	66	29	47	121	440	482
Heptagenia	...	...	...	...	1	...	...	...	...
Leptophlebia	...	...	...	...	...	...	6	1	...
Rhithrogena	...	...	11	3	...	...	1	3	...
Plecoptera									
Acroneuria	...	1	...	1	...	...	...	1	...
Alloperla	...	...	...	1	...	1	...	...	1
Claassenia	6	...	...	...	...	...	2	2	5
Isogenus	...	...	...	...	...	...	1	...	...
Isoperla	...	...	1	...	1	4	15	28	26
Paraleuctra	...	...	1	...	...	...	...	...	...
Nemoura	...	...	...	...	...	1	...	...	...
Pteronarcella	6	8	...	12	10	11	9	83	26

TABLE 10. KAMAS HATCHERY BOTTOM FAUNA ANALYSIS, STATION 5. (Cont'd.)

Organism	4-4-69	5-2-69	6-16-69	7-25-69	8-21-69	9-18-69	11-12-69	1-19-70	3-27-70
Coleoptera									
Dryopidae	...	...	1	...	...	...	...	...	...
Dytiscidae	1	...	1	2	2	...	...	4	...
Elmidae	2	...	...	4	8	2	106	255	170
Gyrinnidae	...	...	...	...	...	...	1	...	...
Halipidae	...	...	...	6	...	...	...	...	...
Hydrophilidae	...	...	...	1	...	...	...	...	...
Diptera									
Antocha	...	...	1	1	...	1	37	76	99
Athrix	14	18	6	6	1	8	4	11	13
Blepharoceridae	...	...	...	...	...	...	...	...	1
Chironomidae	...	...	71	82	7	5	340	2307	1846
Hexatoma	2	...	1	1	1	1	...	2	...
Limnophora	...	...	...	...	...	2	7	13	1
Muscidae	...	...	...	...	...	...	...	3	...
Raphidolabis	...	...	1	1	...	...	...	...	...
Simulidae	...	...	2	10	17	1	1	183	2
Stratiomyidae	...	...	...	...	...	...	31	44	18
Tipulidae	...	1	...	...	...	1	...	2	11
Trichoptera									
Arctopsyche	3	1	2	3	4	19	8	29	59
Brachycentrus	7	...	...	73	11	9	8	46	22
Glossosoma	...	...	...	...	...	...	...	1	2
Hydropsyche	...	13	13	4	3	37	100	495	883
Leptocella	2	1	22	20	15	20	1302	1272	1138
Limnephilus	4	3	35	14	19	...	13	25	28
Rhyacophila	...	...	...	...	...	1	2	8	3
Total Org./sq. ft.	7.3	36.0	68.1	61.9	36.8	82.2	480.8	1238.0	1045.4
Kinds of Organisms	14	14	25	25	19	23	27	30	27

TABLE 11. KAMAS HATCHERY BOTTOM FAUNA ANALYSIS, STATION 6.

Organism	4-4-69	5-2-69	6-16-69	7-25-69	8-21-69	9-18-69	11-12-69	1-19-70	3-27-70
Annelida									
Hirudinea	28	24	7	16	11	7	53	40	90
Oligochaete	...	...	1	...	...	...	...	...	...
Tubifex	6	6	...	5	8	1	102	28	200
Crustacea									
Amphipoda	...	...	...	...	...	8	...	...	...
Asellus	...	...	...	...	...	1	2	...	...
Mollusca									
Gastropoda	4	3	2	3	3	1	22	...	...
Pelecypoda	...	1	...	...	...	...	34	...	10
Ephemeroptera									
Baetis	12	1	213	120	253	9	2	108	1040
Cinygmula	...	...	49	...	...	...	...	...	...
Epeorus	...	...	73	8	...	...	...	...	30
Ephemerella	419	11	282	256	94	74	347	1012	2740
Heptagenia	...	...	...	...	4	...	...	...	...
Leptophlebia	...	...	...	...	...	...	4	...	10
Rhithrogena	...	8	31	10	...	...	3	...	...
Plecoptera									
Acroneuria	2	...	1	7	...	2	...	4	20
Alloperla	1	...	...	...	2	...	2	...	...
Arcynopteryx	...	...	1	...	...	...	...	...	...
Capnia	...	...	...	...	...	...	11	8	20
Claassenia	2	...	10	9	3	...	...	20	20
Isogenus	...	...	...	...	3	...	...	...	...
Isoperla	25	...	6	2	...	2	8	160	70
Paraleuctra	...	...	6	...	...	...	...	40	...
Nemoura	...	...	...	3	4	...	...	...	20
Pteronarcella	114	6	...	19	43	26	30	32	50

TABLE 11. KAMAS HATCHERY BOTTOM FAUNA ANALYSIS, STATION 6. (Cont'd.)

Organism	4-4-69	5-2-69	6-16-69	7-25-69	8-21-69	9-18-69	11-12-69	1-19-70	3-27-70
Coleoptera									
Dryopidae	...	...	1	...	...	...	...	...	...
Elmidae	2	...	...	24	36	1	187	568	870
Halipidae	1	...	...	...	...	...	3	...	...
Diptera									
Antocha	7	1	...	3	3	...	62	92	120
Athrix	5	5	6	8	8	9	4	20	40
Chironomidae	20	1	22	48	52	19	138	572	4270
Hexatoma	...	...	1	3	1	3	...	...	...
Limnophora	...	...	...	...	...	1	...	...	10
Muscidae	...	...	...	...	...	...	12	...	10
Raphidolabis	1	...	1	1	...	...	4	...	...
Simulidae	...	...	59	43	...	2	1	12	40
Stratiomyidae	4	1	...	...	...	...	14	44	60
Tipulidae	25	1	2	...	3	2	1	4	10
Trichoptera									
Arctopsyche	113	...	1	38	91	36	33	68	130
Brachycentrus	161	...	...	25	15	10	77	152	50
Glossosoma	...	...	...	...	...	...	...	36	210
Helicopsyche	...	...	...	...	...	...	1	...	...
Hydropsyche	584	14	59	28	27	26	99	832	470
Leptocella	101	1	1	14	15	22	1711	324	590
Limnephilus	212	15	27	78	58	5	42	92	390
Rhyacophila	25	1	13	10	3	2	7	56	110
Total Org./sq. ft.	187.4	10.0	88.0	80.5	74.0	53.8	603.2	864.8	2340.0
Kinds of Organisms	24	17	25	25	23	23	30	24	29

TABLE 12. MIDWAY HATCHERY BOTTOM FAUNA ANALYSIS, STATION 4.

Organism	8-5-68	4-4-69	5-2-69	6-16-69	7-25-69	8-21-69	9-18-69	11-12-69	1-19-70	3-18-70
Annelida										
Hirudinea	4	22	11	9	5	2	2	13	28	19
Oligochaete	...	7	...	2	...	...	1	1	4	...
Tubifex	...	31	28	52	24	7	4	38	121	113
Crustacea										
Amphipoda	2	7	20	1	5	8	5	4	18	8
Asellus	20	47	32	27	90	180	15	107	407	62
Mollusca										
Gastropoda	...	9	6	6	3	13	...	9	19	3
Pelecypoda	...	...	...	...	...	...	...	3	2	2
Ephemeroptera										
Baetis	...	127	35	117	79	10	2	9	77	271
Epeorus	...	...	...	1	...	...	...	...	...	...
Ephemerella	...	...	37	114	50	7	...	17	60	221
Heptagenia	2	...	...	...	...	...	...	...	...	...
Plecoptera										
Isoperla	...	...	...	...	...	1	...	...	...	...
Coleoptera										
Dryopidae	...	...	...	1	...	...	...	...	...	...
Elmidae	...	3	5	2	7	4	5	95	112	138
Diptera										
Antocha	...	...	...	...	...	...	...	...	...	1
Chironomidae	...	5	6	1	17	2	1	37	75	162
Limnophora	...	...	...	...	...	...	...	...	2	...
Raphidolabis	...	1	...	...	...	...	...	...	...	...
Simulidae	...	...	...	...	3	2	...	21	59	5
Tipulidae	...	...	...	...	...	...	...	...	1	...

TABLE 12. MIDWAY HATCHERY BOTTOM FAUNA ANALYSIS, STATION 4. (Cont'd.)

Organism	8-5-68	4-4-69	5-2-69	6-16-69	7-25-69	8-21-69	9-18-69	11-12-69	1-19-70	3-18-70
Trichoptera										
Brachycentrus	...	4	...	...	...	...	...	6	2	...
Hydropsyche	...	...	...	...	...	...	...	...	3	2
Leptocella	...	...	...	...	...	...	...	17	...	...
Limnephilus	12	3	...	19	3	3	...	16	46	6
Rhyacophila	...	...	...	...	...	...	...	...	1	...
Total Org./sq.ft.	4.0	26.6	18.0	35.2	28.6	48.0	7.0	78.6	207.4	202.6
Kinds of Organisms	5	12	9	13	11	12	8	15	18	14

TABLE 13. MIDWAY HATCHERY BOTTOM FAUNA ANALYSIS, STATION 5.

Organism	8-5-68	4-4-69	5-2-69	6-16-69	7-25-69	8-21-69	9-18-69	11-12-69	1-19-70	3-18-70
Annelida										
Hirudinea	6	92	87	30	17	43	6	63	100	43
Oligochaete	...	3	...	...	...	...	...	1	1	953
Tubifex	2	91	214	31	20	383	2	296	2117	...
Crustacea										
Amphipoda	58	27	2	25	21	51	19	1265	217	15
Asellus	55	48	29	134	258	715	47	2281	499	50
Mollusca										
Gastropoda	3	10	18	11	3	36	2	530	52	5
Pelecypoda	...	...	9	...	...	...	...	6	4	5
Ephemeroptera										
Baetis	2	172	21	254	19	25	...	37	20	26
Ephemerella	...	...	6	117	26	1	...	49	12	12
Rhithrogena	...	...	...	1	...	...	...	...	...	...
Tricorythodes	...	...	...	...	...	2	...	...	...	...
Coleoptera										
Dytiscidae	...	...	...	...	...	1	...	...	...	...
Elmidae	...	...	...	8	...	2	...	39	35	6
Hydraenidae	1	...	...	...	...	...	...	...	...	...
Diptera										
Chironomidae	1	151	244	117	3	12	...	530	332	151
Limnophora	...	...	...	...	...	...	...	6	1	...
Simulidae	3	4	...	13	7	3	...	190	17	3
Stratiomyidae	...	...	...	1	...	...	...	...	...	...
Trichoptera										
Brachycentrus	...	...	...	...	...	...	...	...	9	...
Hydropsyche	...	...	...	...	...	...	...	1	...	...
Leptocella	...	...	...	...	...	...	...	1	...	...
Limnephilus	1	...	...	8	3	...	...	24	...	...
Total Org./sq.ft.	13.2	59.8	63.0	75.0	37.7	254.8	15.2	1063.8	683.2	253.8
Kinds of Organisms	10	9	9	13	10	12	5	16	14	11

TABLE 14. MIDWAY HATCHERY BOTTOM FAUNA ANALYSIS, STATION 6.

Organism	8-5-68	4-4-69	5-2-69	6-16-69	7-25-69	8-21-69	9-18-69	11-12-69	1-19-70	3-18-70
Annelida										
Hirudinea	36	114	93	65	31	7	...	254	319	479
Oligochaete	...	...	...	...	...	...	1	...	...	1
Tubifex	1	64	64	32	68	642	3	1124	949	553
Crustacea										
Amphipoda	20	5	5	...	5	1	4	278	55	24
Asellus	162	39	14	47	156	163	10	4490	139	30
Mollusca										
Gastropoda	...	13	5	...	3	3	3	783	18	1
Pelecypoda	...	...	...	...	...	1	...	137	10	4
Ephemeroptera										
Baetis	8	303	51	156	66	...	...	5	67	459
Ephemerella	...	...	7	16	30	2	...	30	15	36
Heptagenia	36	...	...	...	1	...	...	...	...	...
Tricorythodes	...	...	...	...	60	5	...	...	...	...
Hemiptera										
Corixidae	...	...	...	...	...	1	...	89	...	...
Coleoptera										
Dryopidae	1	...	...	...	...	...	...	...	...	...
Dytiscidae	3	...	...	...	...	2	...	...	...	1
Elmidae	...	3	...	...	7	1	...	71	4	16
Halipidae	...	...	...	...	...	...	...	1	...	...
Diptera										
Anthomyiidae	...	1	...	...	...	...	...	...	...	...
Chironomidae	5	209	38	190	5	5	...	137	93	399
Limnophora	...	...	...	...	...	...	...	1	...	...
Simulidae	24	12	...	46	8	5	...	5	107	46

TABLE 14. MIDWAY HATCHERY BOTTOM FAUNA ANALYSIS, STATION 6. (Cont'd.)

Organism	8-5-68	4-4-69	5-2-69	6-16-69	7-25-69	8-21-69	9-18-69	11-12-69	1-19-70	3-18-70
Trichoptera										
Brachycentrus	1	1	...	...	...	...	...	...	...	...
Hydropsyche	...	...	...	...	...	...	...	...	...	1
Limnephilus	...	...	...	1	...	4	5	77	5	2
Total Org./sq.ft.	29.7	76.4	27.7	55.3	44.0	168.4	5.2	1496.4	356.2	410.4
Kinds of Organisms	11	11	8	8	12	14	6	15	12	15

TABLE 15. LOA HATCHERY BOTTOM FAUNA ANALYSIS, STATION 1.

Organism	5-9-69	6-4-69	7-16-69	8-21-69	9-18-69	11-21-69	1-13-70	3-11-70
Annelida								
Hirudinea	9	5	9	3	5	18	87	9
Tubifex	...	3	2	2	6	19	19	5
Crustacea								
Amphipoda	717	662	134	40	214	350	2646	319
Mollusca								
Gastropoda	48	322	7	15	75	48	178	68
Pelecypoda	1	7	...	...	...	...	...	...
Ephemeroptera								
Baetis	...	...	1	1	6	1	...	...
Ephemerella	...	...	...	...	...	...	1	...
Plecoptera								
Acroneuria	1	...	...	10	1	34	21	7
Odonata								
Argia	1	12	3	...	...	7	87	2
Hemiptera								
Ambrysus	1	17	2	...	...	...	...	...
Coleoptera								
Dytiscidae	...	...	...	...	...	...	63	...
Elmidae	7	7	1	3	...	91	151	133
Diptera								
Chironomidae	...	...	...	1	...	2	4	1
Muscidae	...	...	...	...	...	2	...	...
Raphidolabis	...	...	...	...	...	2	...	...
Simulidae	...	...	...	...	...	...	...	1

TABLE 15. LOA HATCHERY BOTTOM FAUNA ANALYSIS, STATION 1. (Cont'd.)

Organism	5-9-69	6-4-69	7-16-69	8-21-69	9-18-69	11-21-69	1-13-70	3-11-70
Trichoptera								
Glossosoma	...	...	...	...	...	7	...	2
Helicopsyche	...	116	12	...	33	14	...	1
Hydropsyche	...	1	...	3	...	3	14	2
Leptocella	...	1	...	...	...	128	...	13
Limnephilus	1	4	...	11	2	24	195	...
Total Org./sq.ft.	393.0	385.6	57.0	29.6	114.0	250.0	1155.2	187.7
Kinds of Organisms	9	12	9	10	8	16	12	13

TABLE 16. LOA HATCHERY BOTTOM FAUNA ANALYSIS, STATION 3.

Organism	5-9-69	6-4-69	7-16-69	8-21-69	9-18-69	11-21-69	1-13-70	3-11-70
Annelida								
Hirudinea	12	18	5	17	9	27	59	9
Oligochaete	1	...	...	...	2	...	...	...
Tubifex	152	135	265	44	24	24	1357	101
Crustacea								
Amphipoda	356	370	642	1031	1021	475	1844	924
Mollusca								
Gastropoda	15	13	167	39	7	1	14	...
Pelecypoda	2	...	...	...	...	...	3	3
Ephemeroptera								
Baetis	...	28	28	22	77	8	17	18
Ephemerella	...	...	...	...	...	...	1	...
Plecoptera								
Acroneuria	...	...	...	...	...	...	1	2
Isogenus	4	4	...	...	...	...	...	...
Coleoptera								
Dytiscidae	1	...	1	...	...	...	...	...
Elmidae	...	...	...	1	...	3	...	10
Diptera								
Athrix	...	...	...	...	...	1	...	...
Chironomidae	71	36	3	16	2	13	70	134
Limnophora	...	1	...	3	2	...	...	...
Raphidolabis	...	...	...	...	...	...	...	1
Simulidae	1	...	31	66	46	4	77	4
Tipulidae	...	...	...	...	...	...	3	...

TABLE 16. LOA HATCHERY BOTTOM FAUNA ANALYSIS, STATION 3. (Cont'd.)

Organism	5-9-69	6-4-69	7-16-69	8-21-69	9-18-69	11-21-69	1-13-70	3-11-70
Trichoptera								
Helicopsyche	...	...	2	3	12	...	...	...
Hydropsyche	1	1	...	...	...	...	13	4
Leptocella	...	...	...	1	1	1	1	...
Limnephilus	...	5	...	24	30	2	2	...
Total Org./sq.ft.	305.3	203.6	381.3	422.3	411.0	186.3	1155.2	403.3
Kinds of Organisms	11	10	9	12	12	11	14	11

TABLE 17. LOA HATCHERY BOTTOM FAUNA ANALYSIS, STATION 4.

Organism	5-9-69	6-4-69	7-16-69	8-21-69	9-18-69	11-21-69	1-13-70	3-11-70
Annelida								
Hirudinea	2	44	53	53	56	14	51	33
Tubifex	31	77	30	244	19	19	45	35
Crustacea								
Amphipoda	943	1650	1805	1531	1263	1463	6617	2460
Mollusca								
Gastropoda	2	46	272	45	189	7	...	1
Pelecypoda	...	...	...	...	...	3	...	...
Ephemeroptera								
Baetis	1	101	34	50	33	31	15	29
Caenis	1	...	...	...	...	...	...	...
Plecoptera								
Acroneuria	...	...	...	...	...	...	...	4
Isogenus	11	39	...	...	...	...	...	...
Isoperla	...	...	3	...	...	...	...	...
Coleoptera								
Dytiscidae	1	3	2	...	...	...	...	...
Elmidae	...	...	...	1	1	...	...	...
Diptera								
Athrix	...	...	...	...	1	...	...	...
Chironomidae	17	24	1	7	1	33	139	116
Limnophora	...	...	...	...	...	...	1	...
Muscidae	...	...	...	...	...	1	...	...
Simulidae	...	1	22	63	23	44	174	56
Tipulidae	1	1	...	...	...	...	1	...

TABLE 17. LOA HATCHERY BOTTOM FAUNA ANALYSIS, STATION 4. (Cont'd.)

Organism	5-9-69	6-4-69	7-16-69	8-21-69	9-18-69	11-21-69	1-13-70	3-11-70
Trichoptera								
Helicopsyche	...	...	1	...	...	...	1	...
Hydropsyche	...	4	2	...	...	5	6	...
Leptocella	1	...	...	...	1	...	...	2
Limnephilus	4	28	16	5	2	4	40	...
Total Org./sq.ft.	338.3	672.8	747.0	666.3	529.6	550.3	2363.2	912.0
Kinds of Organisms	12	12	12	9	11	11	11	9

TABLE 18. WHITE HATCHERY BOTTOM FAUNA ANALYSIS, STATION 5.

Organism	10-23-68	1-7-69	5-27-69	6-24-69	7-22-69	8-19-69	9-19-69	11-14-69	1-16-70	3-20-70
Annelida										
Hirudinea	15	12	...	...	2	1	7	25	60	260
Oligochaete	...	...	...	2	...	...	...	...	...	...
Tubifex	...	52	4	55	143	10	...	135	380	3910
Crustacea										
Amphipoda	22	39	...	...	...	2	2	3	...	...
Decapoda	2	...	...	...	...	...	...	...	...	...
Mollusca										
Gastropoda	26	25	...	...	1	9	...	356	1210	3590
Pelecypoda	...	...	...	...	...	...	...	1	...	...
Ephemeroptera										
Baetis	...	1	19	13	102	40	...	4	50	1120
Epeorus	...	...	2	2	...	...	...	...	...	...
Ephemerella	...	1	37	215	210	23	...	57	380	980
Heptagenia	...	...	...	...	32	...	...	...	...	...
Leptophlebia	...	...	...	...	6	4	1	...	...	...
Rhithrogena	...	...	6	42	...	...	...	...	...	10
Tricorythodes	...	...	...	...	1047	6	...	...	...	30
Plecoptera										
Acroneuria	...	...	...	...	1	...	...	...	...	50
Arcynopteryx	...	...	2	...	...	...	...	1	...	40
Brachyptera	...	...	...	...	...	...	...	...	...	100
Capnia	...	...	...	...	...	...	...	2	10	...
Claassenia	...	...	...	...	...	...	...	...	20	...
Isogenus	3	...	...	...	...	...	...	...	...	...
Isoperla	...	...	19	5	19	17	...	2	...	10
Nemoura	...	...	...	...	...	...	...	...	10	...
Pteronarcella	...	...	...	...	1	7	...	...	10	40

TABLE 18. WHITE HATCHERY BOTTOM FAUNA ANALYSIS, STATION 5. (Cont'd.)

Organism	10-23-68	1-7-69	5-27-69	6-24-69	7-22-69	8-19-69	9-19-69	11-14-69	1-16-70	3-20-70
Coleoptera										
Dryopidae	4	1	...	...	...	...	...	...	...	...
Dytiscidae	...	3	...	...	6	2	...	...	...	...
Elmidae	1	12	...	...	26	42	...	50	300	1060
Diptera										
Antocha	...	...	...	...	1	...	...	...	...	10
Chironomidae	4	163	...	167	132	16	17	1004	2220	3450
Hexatoma	3	...	...	...	1	8	...	...	...	...
Limnophora	...	...	...	...	...	3	1	3	30	50
Raphidolabis	...	...	...	1	2	1	...	...	...	10
Simulidae	...	...	...	1	1	24	...	5	...	...
Stratiomyidae	...	...	...	...	...	...	...	5	20	30
Tipulidae	26	28	2	...	1	27	2	30	50	27
Trichoptera										
Arctopsyche	2	...	...	...	...	...	...	...	...	...
Brachycentrus	5	...	2	...	...	1	...	...	...	...
Hydroptila	...	...	...	...	...	1	...	...	...	...
Hydropsyche	...	4	30	...	3	8	...	...	10	90
Leptocella	...	...	1	...	...	...	...	...	10	20
Rhyacophila	...	...	1	...	...	3	...	...	10	...
Total Org./sq.ft.	11.3	34.1	12.5	50.3	173.7	51.0	6.0	337.8	956.0	2977.4
Kinds of Organisms	13	11	12	10	20	22	7	16	17	21

TABLE 19. WHITE HATCHERY BOTTOM FAUNA ANALYSIS, STATION 8.

Organism	10-23-68	1-7-69	5-27-69	6-24-69	7-22-69	8-19-69	9-19-69	11-14-69	1-16-70	3-20-70
Annelida										
Hirudinea	6	46	...	1	1	6	14	15	60	140
Oligochaete	...	...	...	...	...	...	1	1	20	...
Tubifex	...	1	174	83	24	8	...	68,833	36,430	810
Crustacea										
Amphipoda	12	13	...	12	8	14	9	49	190	80
Mollusca										
Gastropoda	...	...	...	...	...	...	1	3	10	...
Ephemeroptera										
Baetis	...	1	81	39	3	1	...	1	160	220
Epeorus	...	...	4	...	...	...	...	...	...	...
Ephemerella	...	...	124	31	1	...	...	...	10	50
Rhithrogena	...	...	4	1	1	...	...	...	...	...
Plecoptera										
Arcynopteryx	...	...	1	...	...	...	...	...	...	...
Isoperla	...	1	17	2	...	...	...	...	...	10
Pteronarcella	...	...	...	...	...	1	...	1	...	...
Pteronarcys	...	...	...	...	1	...	...	...	...	...
Coleoptera										
Dytiscidae	...	...	...	...	...	...	...	...	...	10
Elmidae	...	...	...	...	1	1	...	5	30	40
Diptera										
Chironomidae	1	197	...	82	37	45	...	617	4940	2990
Hexatoma	...	...	...	...	...	1	...	...	...	...
Simulidae	...	...	3	...	151	653	29	110	720	...
Stratiomyidae	...	...	...	...	...	...	...	...	10	...
Tipulidae	...	...	...	1	...	...	...	...	10	10

TABLE 19. WHITE HATCHERY BOTTOM FAUNA ANALYSIS, STATION 8. (Cont'd.)

Organism	10-23-68	1-7-69	5-27-69	6-24-69	7-22-69	8-19-69	9-19-69	11-14-69	1-16-70	3-20-70
Trichoptera										
Hydropsyche	...	4	24	11	1	1	...	1	...	20
Limnephilus	3	...	...	...	...	...	...	...	...	...
Total Org./sq.ft.	2.2	26.3	43.2	26.3	22.9	146.2	10.8	13,927.2	8498.0	876.0
Kinds of Organisms	4	7	9	10	11	10	5	11	12	11

TABLE 20. WHITE HATCHERY BOTTOM FAUNA ANALYSIS, STATION 9.

Organism	10-23-68	1-7-69	5-27-69	6-24-69	7-22-69	8-19-69	9-19-69	11-14-69	1-16-70	3-20-70
Annelida										
Hirudinea	4	1	2	...	...	4	5	40	12	50
Oligochaete	...	2	...	...	...	...	3	40	12	...
Tubifex	...	68	21	1	29	126	1	95,550	264	1330
Crustacea										
Amphipoda	...	3	...	...	2	3	2	130	178	30
Asellus	...	...	...	...	...	...	...	20	...	...
Mollusca										
Gastropoda	...	3	...	...	...	9	23	170	75	...
Ephemeroptera										
Baetis	...	...	78	195	85	26	2	130	307	1670
Epeorus	...	1	1	10	...	...	...	...	...	...
Ephemerella	...	2	108	248	1	...	...	160	82	250
Heptagenia	...	...	...	...	2	...	...	...	...	...
Leptophlebia	...	...	...	...	...	...	...	...	...	10
Rhithrogena	...	...	11	...	...	...	...	...	...	40
Tricorythodes	...	...	...	...	8	...	...	...	...	...
Plecoptera										
Acroneuria	...	...	...	...	...	...	...	...	...	40
Arcynopteryx	...	3	...	...	...	...	1	...	5	10
Brachyptera	...	...	...	...	...	...	...	...	2	160
Isogenus	...	...	...	...	...	...	...	10	...	...
Isoperla	...	1	33	...	...	3	...	20	28	...
Pteronarcella	2	...	...	...	4	1	1	...	12	20
Pteronarcys	...	...	...	...	1	...	...	...	...	...
Coleoptera										
Elmidae	...	...	...	...	2	...	...	590	109	210

TABLE 20. WHITE HATCHERY BOTTOM FAUNA ANALYSIS, STATION 9. (Cont'd.)

Organism	10-23-68	1-7-69	5-27-69	6-24-69	7-22-69	8-19-69	9-19-69	11-14-69	1-16-70	3-20-70
Diptera										
Chironomidae	2	72	1	98	33	440	18	1690	1977	1710
Hexatoma	...	...	1	...	4	...	...	...	...	...
Limnophora	...	...	...	...	...	...	...	10	9	10
Raphidolabis	...	...	...	...	1	...	...	...	...	30
Sciomyzidae	...	1	...	...	...	...	...	...	...	...
Simulidae	...	...	...	13	218	47	13	470	312	330
Stratiomyidae	1	...	...	...	...	...	...	10	6	...
Tipulidae	7	9	...	...	3	...	7	20	2	10
Trichoptera										
Brachycentrus	...	1	...	...	2	...	...	...	...	...
Hydropsyche	...	4	15	18	8	...	...	90	63	50
Leptocella	...	...	...	...	...	...	...	...	1	...
Limnephilus	...	...	1	2	...	...	...	...	1	10
Rhyacophila	...	...	...	...	...	...	...	...	1	...
Total Org./sq.ft.	1.6	17.1	27.2	60.2	40.3	131.8	15.2	19,830.0	691.6	1194.0
Kinds of Organisms	5	14	11	8	16	9	11	17	21	19

TABLE 21. SPRINGVILLE STATE HATCHERY BOTTOM FAUNA ANALYSIS, STATION 1.

Organism	4-10-69	5-2-69	6-16-69	7-23-69	8-21-69	9-18-69	11-12-69	1-19-70	3-18-70
Annelida									
Hirudinea	11	24	59	19	38	10	49	47	20
Oligochaete	1	...	...	...	...	...	...	...	...
Tubifex	...	25	96	...	...	...	133	285	220
Crustacea									
Amphipoda	63	192	300	624	1314	37	2953	1423	3170
Mollusca									
Gastropoda	4	20	5	...	99	...	96	1786	330
Ephemeroptera									
Ameletus	...	...	...	...	1	...	...	...	...
Baetis	284	155	15	6	...	...	58	42	1040
Ephemerella	1	2	13	3	...	...	...	32	10
Tricorythodes	...	278	...	...	46	1	...	...	570
Plecoptera									
Acroneuria	...	3	...	...	...	...	...	...	...
Isoperla	...	1	...	...	...	...	...	...	...
Odonata									
Argia	...	1	...	...	...	...	...	...	...
Ischnur	...	...	...	...	2	...	1	3	...
Hemiptera									
Corixdae	...	...	...	1	1	...	...	...	...
Coleoptera									
Elmidae	1	...	...	...	...	...	...	32	10

TABLE 21. SPRINGVILLE STATE HATCHERY BOTTOM FAUNA ANALYSIS, STATION 1. (Cont'd.)

Organism	4-10-69	5-2-69	6-16-69	7-23-69	8-21-69	9-18-69	11-12-69	1-19-70	3-18-70
Diptera									
Chironomidae	18	6	454	8	6	5	43	172	730
Limnophora	...	...	...	...	...	...	1	...	...
Simulidae	...	1	...	...	1	...	13	10	...
Trichoptera									
Hydropsyche	...	...	...	...	...	...	1	2	...
Total Org./sq.ft.	40.5	70.8	94.2	132.2	301.6	10.6	669.6	766.8	1220.0
Kinds of Organisms	8	12	7	6	9	4	10	11	9

TABLE 22. SPRINGVILLE STATE HATCHERY BOTTOM FAUNA ANALYSIS, STATION 4.

Organism	4-10-69	5-2-69	6-16-69	7-23-69	8-21-69	9-18-69	11-12-69	1-19-70	3-18-70
Annelida									
Hirudinea	35	21	65	1	209	1	90	115	120
Tubifex	603	2789	6350	1901	4	22	1421	1079	1310
Crustacea									
Amphipoda	75	892	3933	25	2922	...	7370	5371	6710
Asellus	...	1	...	...	...	...	...	...	...
Mollusca									
Gastropoda	4	11	14	...	29	2	6	205	110
Pelecypoda	...	3	13	4	...	...	8	...	...
Ephemeroptera									
Baetis	47	11	256	...	322	...	111	281	2730
Ephemerella	...	...	34	...	...	...	...	5	10
Tricorythodes	2	68	...	...	2	...	...	...	250
Odonata									
Ischnura	...	...	...	...	...	...	...	1	...
Coleoptera									
Elmidae	...	1	1	...	...	...	3	53	90
Diptera									
Chironomidae	58	149	254	2640	22	3	14	1104	8030
Limnophora	...	...	...	...	...	...	2	5	...
Simulidae	...	...	3	...	57	...	76	441	20
Trichoptera									
Hydropsyche	12	7	5	...	18	...	97	66	10
Total Org./sq.ft.	83.6	393.5	1092.8	18,284.0	717.4	5.6	1839.6	1745.2	3878.0
Kinds of Organisms	8	11	11	5	9	4	11	12	11

TABLE 23. SPRINGVILLE FEDERAL HATCHERY BOTTOM FAUNA ANALYSIS, STATION 7.

Organism	4-10-69	5-2-69	6-16-69	7-23-69	8-21-69	9-18-69	11-12-69	1-19-70	3-18-70
Annelida									
Hirudinea	156	22	122	34	19	21	4	7	90
Tubifex	174	526	1016	774	508	4	264	273	4590
Crustacea									
Amphipoda	2620	444	1614	144	397	4	166	440	5440
Mollusca									
Gastropoda	62	29	6	5	39	...	...	8	80
Ephemeroptera									
Baetis	3	149	20	...	11	...	1	112	520
Ephemerella	...	...	82	...	...	...	...	5	120
Tricorythodes	1	271	...	...	...	...	...	...	...
Coleoptera									
Elmidae	...	...	...	...	...	...	...	3	10
Diptera									
Chironomidae	155	86	6	335	2	...	2	19	860
Simulidae	...	1	...	5	1	...	2	106	10
Trichoptera									
Hydropsyche	12	5	...	...	3	3	5	32	130
Hydroptila	...	...	...	...	1	...	...	...	...
Leptocella	...	...	...	...	...	...	1	...	...
Limnephilus	6	...	1	1	...	...	...	9	40
Total Org./sq.ft.	318.9	153.3	286.7	1730.6	196.2	6.4	89.0	202.8	2378.0
Kinds of Organisms	9	9	8	7	9	4	8	11	11

TABLE 24. SPRINGVILLE FEDERAL HATCHERY BOTTOM FAUNA ANALYSIS, STATION 14.

Organism	4-10-69	5-2-69	6-16-69	7-23-69	8-21-69	9-18-69	11-12-69	1-19-70	3-18-70
Annelida									
Hirudinea	20	26	91	103	66	34	142	280	390
Tubifex	322	128	762	492	43	11	551	2370	3620
Crustacea									
Amphipoda	285	209	1563	200	174	31	273	1850	4090
Mollusca									
Gastropoda	2	4	14	5	1	...	...	...	20
Ephemeroptera									
Baetis	41	4	124	6	15	1	12	430	300
Ephemerella	12	...	3	1	...	...	6	30	70
Heptagenia	...	...	...	2	...	...	...	...	...
Tricorythodes	...	1	...	2	...	...	...	...	20
Odonata									
Argia	1	...	2	...	1	...	4	...	...
Hemiptera									
Corixidae	...	...	1	...	...	...	...	...	...
Coleoptera									
Dytiscidae	1	...	...	...	...	...	...	...	...
Elmidae	18	3	2	...	5	...	180	510	250
Diptera									
Athrix	...	...	...	1	...	...	...	...	...
Chironomidae	255	13	18	1	1	...	238	1050	710
Simulidae	2	4	23	1	...	...	7	50	...

TABLE 24. SPRINGVILLE FEDERAL HATCHERY BOTTOM FAUNA ANALYSIS, STATION 14. (Cont'd.)

Organism	4-10-69	5-2-69	6-16-69	7-23-69	8-21-69	9-18-69	11-12-69	1-19-70	3-18-70
Trichoptera									
Arctopsyche	...	...	...	1	...	...	...	...	...
Brachycentrus	...	...	...	1	...	...	...	...	...
Hydropsyche	78	5	971	276	82	1	1895	590	820
Limnephilus	6	1	97	7	2	1	...	50	40
Total Org./sq.ft.	104.4	39.8	367.7	219.8	78.2	15.8	661.6	1442.0	2066.0
Kinds of Organisms	13	11	13	15	10	6	10	10	11

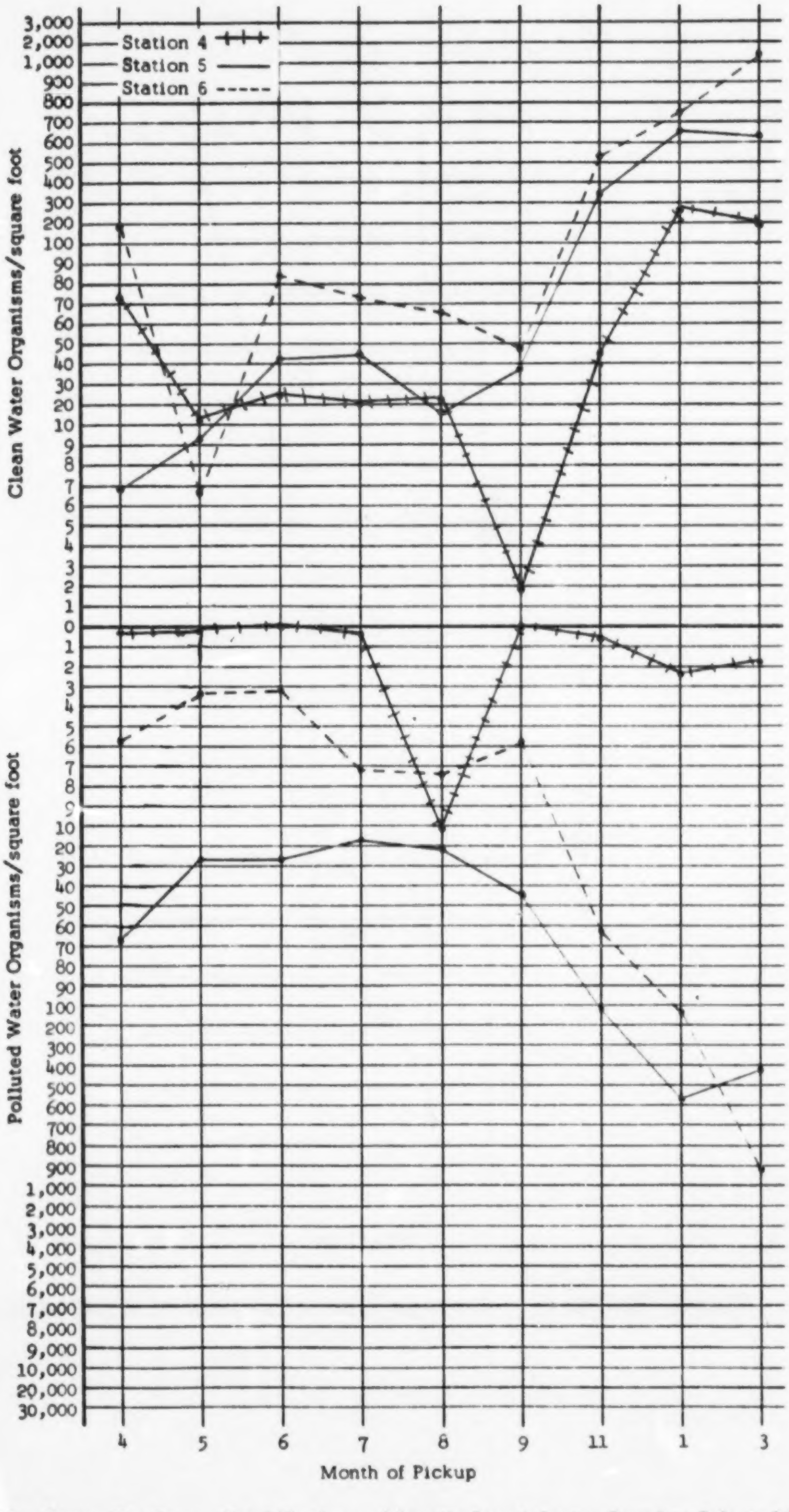

Figure 193. Kamas Hatchery. Total Numbers of Aquatic Invertebrates Found at Selected Stations.

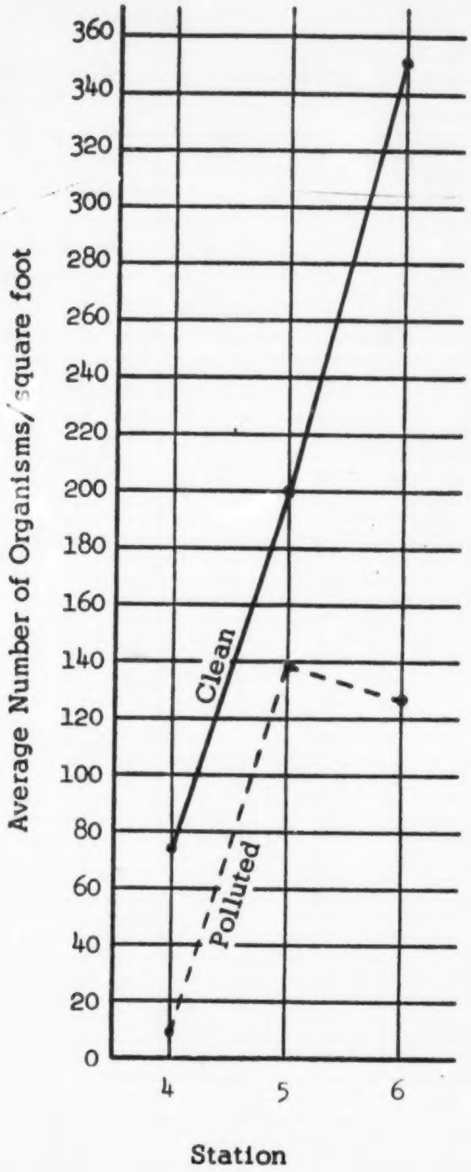

Figure 194. Kamas Hatchery, Average Concentration of Aquatic Invertebrates.

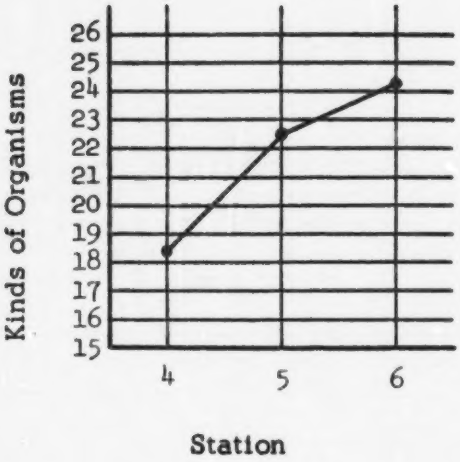

Figure 195. Kamas Hatchery, Average Number of Kinds at Selected Stations.

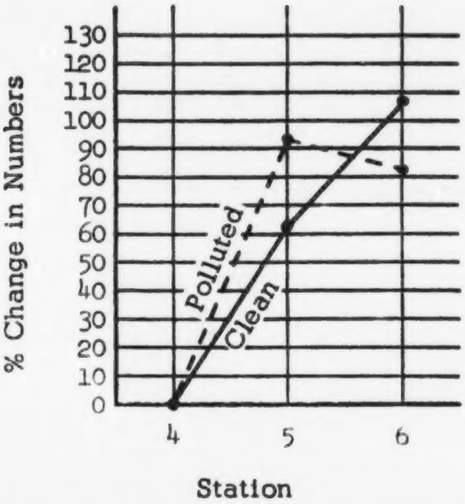

Figure 196. Kamas Hatchery, Per Cent Change in Aquatic Invertebrate Concentration.

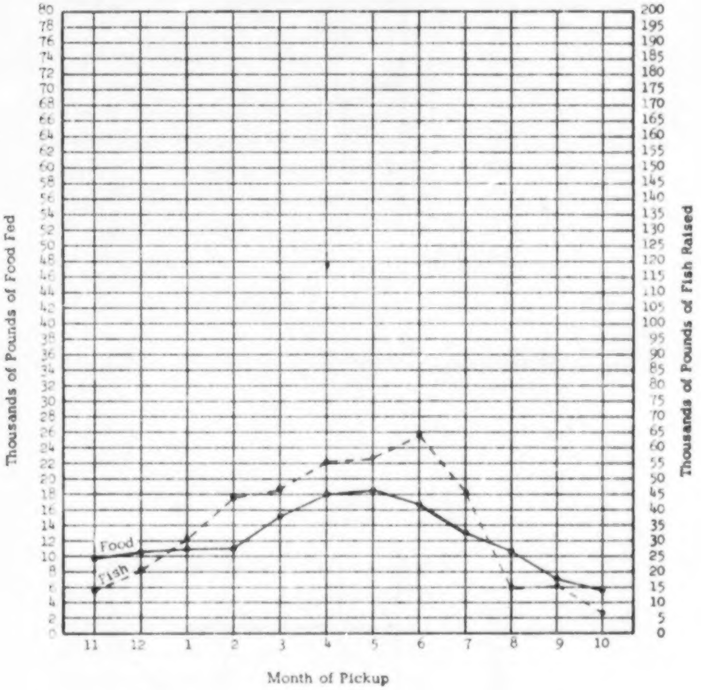

Figure 197. Kamas Hatchery, Feed and Fish Fed During the Sampling Period.

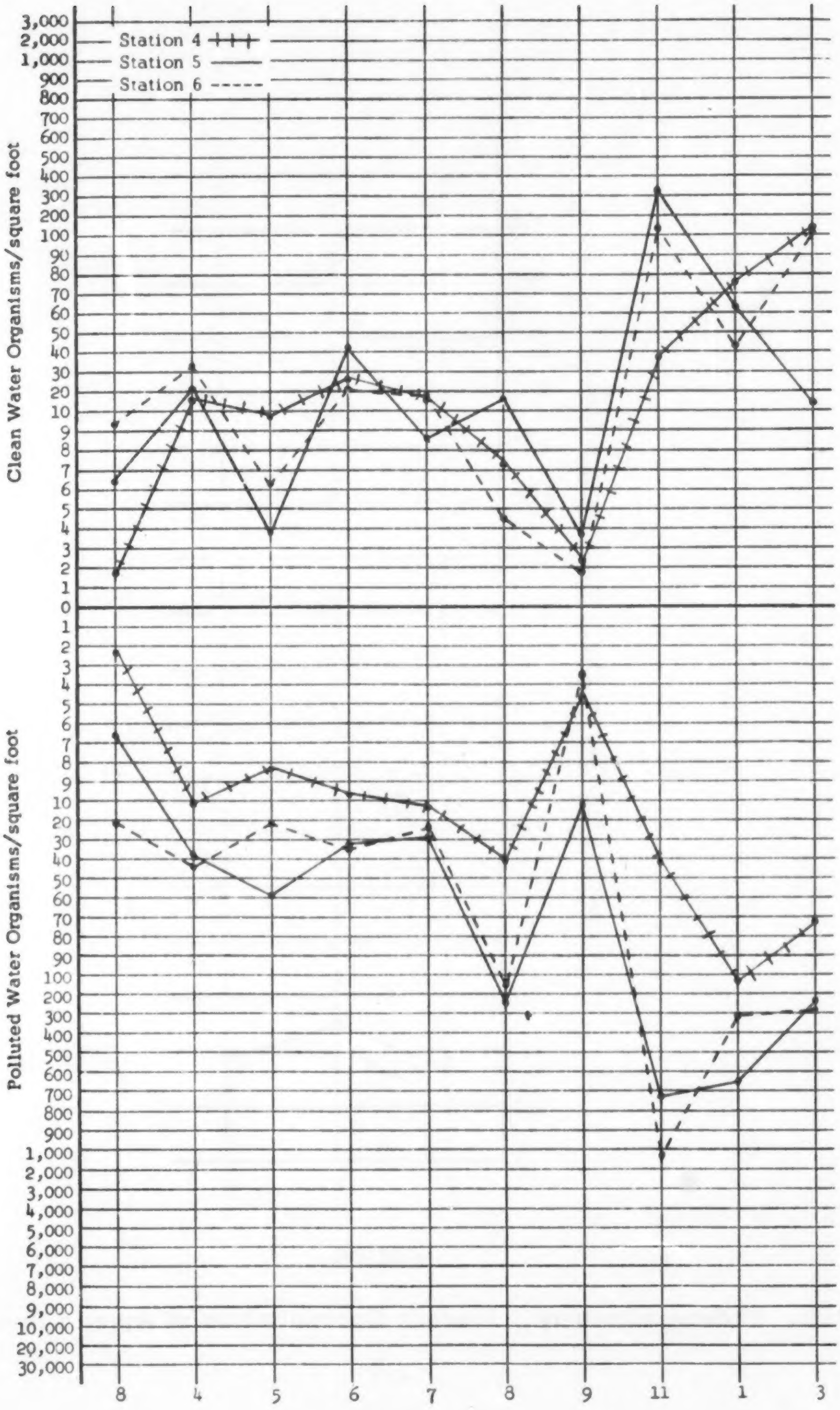

Figure 198. Midway Hatchery, Total Numbers of Aquatic Invertebrates Found at Selected Stations.

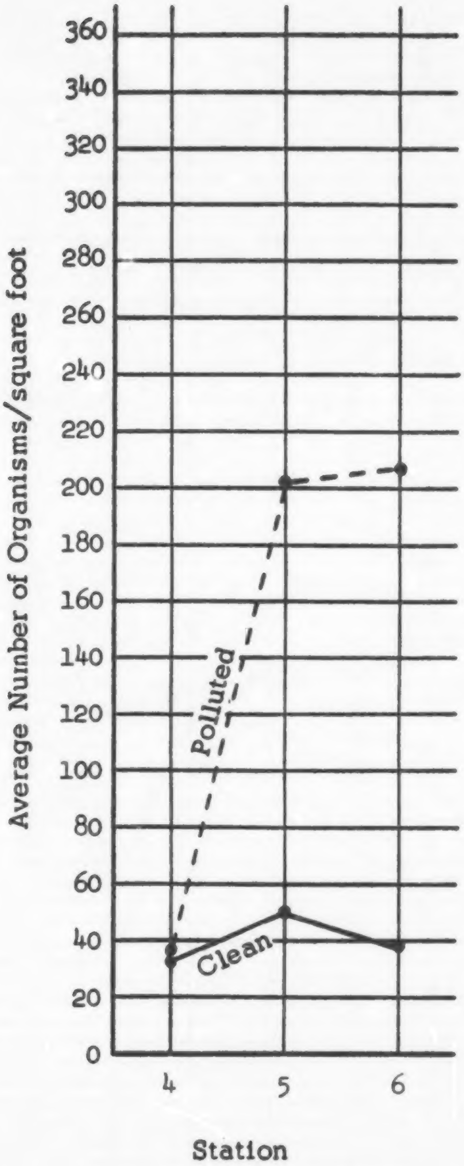

Figure 199. Midway Hatchery, Average Concentration of Aquatic Invertebrates.

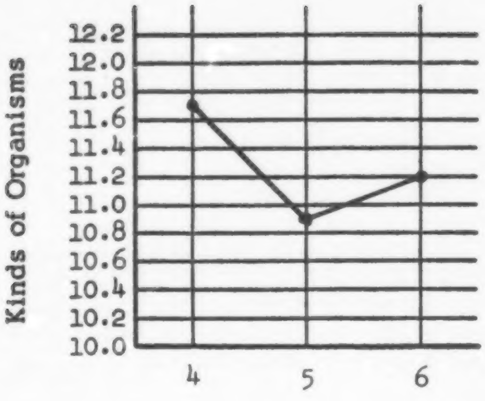

Figure 200. Midway Hatchery, Average Number of Kinds at Selected Stations.

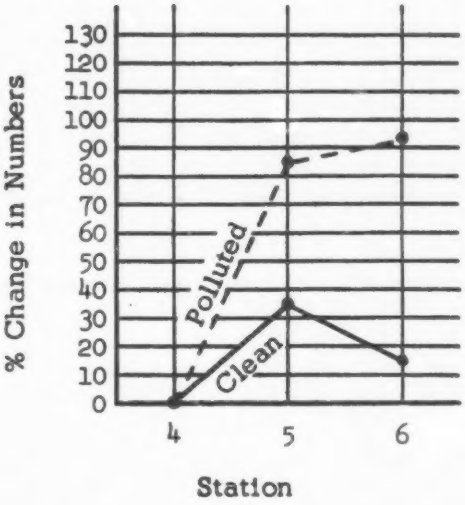

Figure 201. Midway Hatchery, Per Cent Change in Aquatic Invertebrate Concentration.

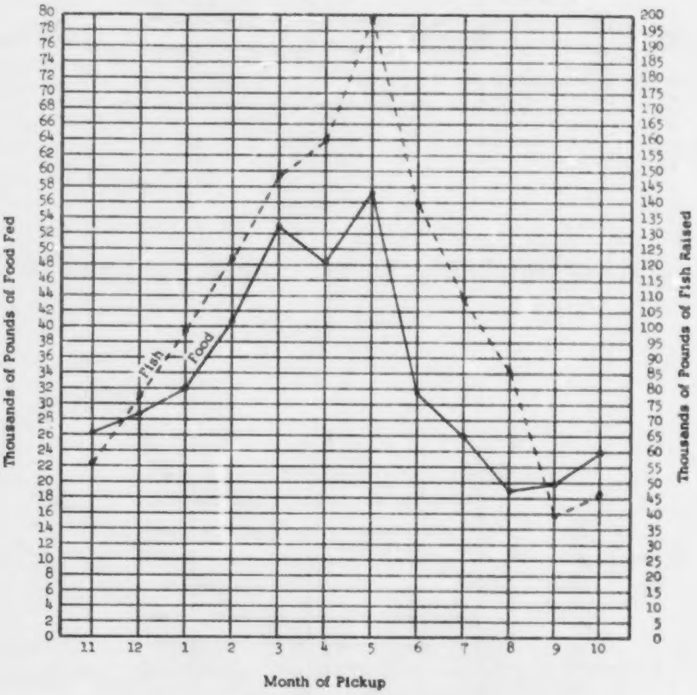

Figure 202. Midway Hatchery, Feed and Fish Fed During the Sampling Period.

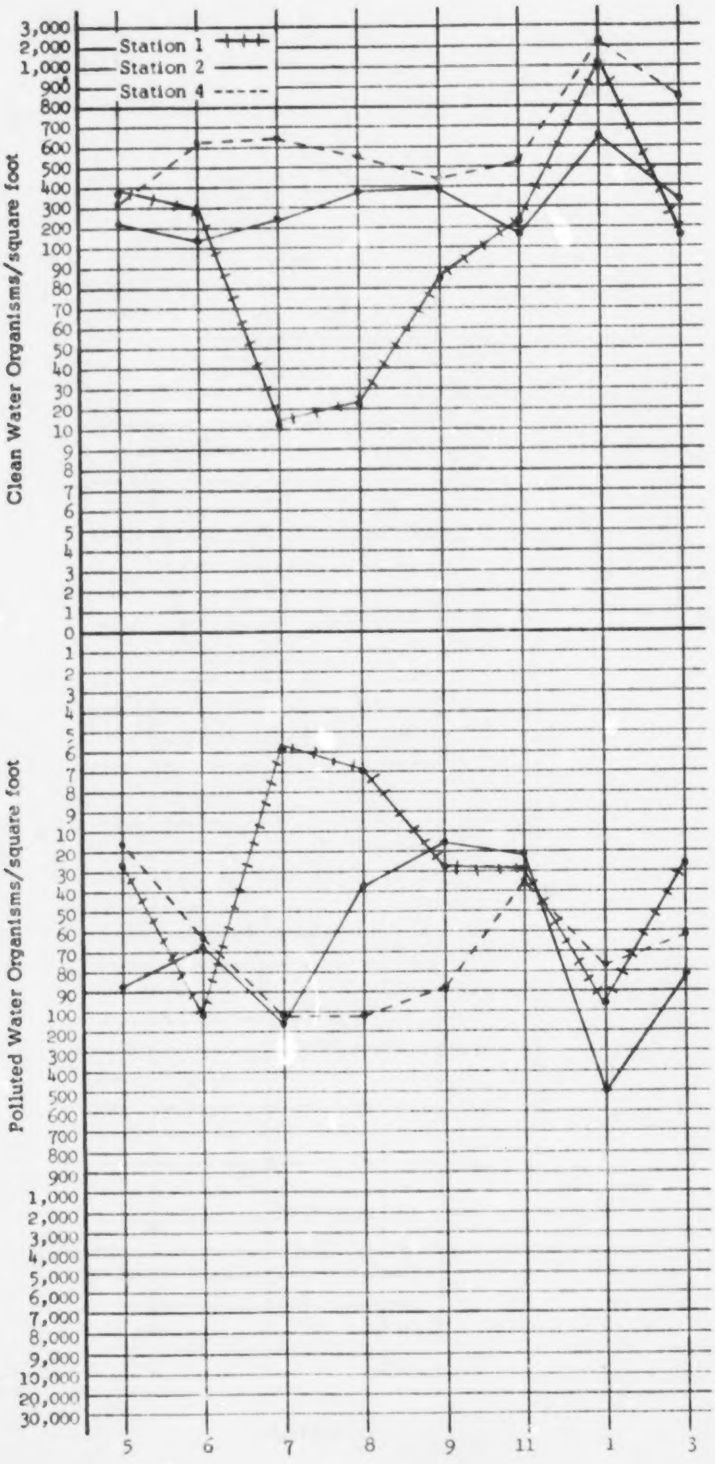

Figure 203. Loa Hatchery, Total Numbers of Aquatic Invertebrates Found at Selected Stations.

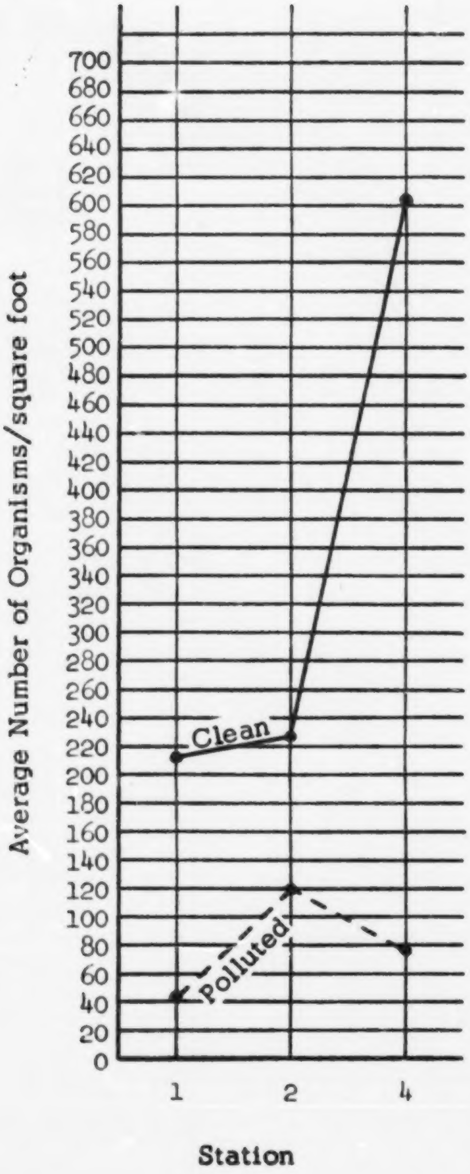

Figure 204. Loa Hatchery, Average Concentration of Aquatic Invertebrates.

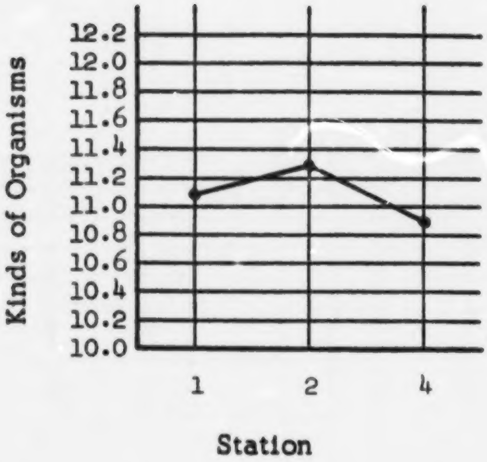

Figure 205. Loa Hatchery, Average Number of Kinds at Selected Stations.

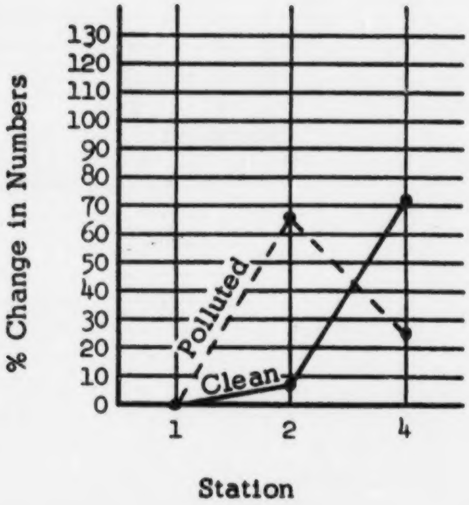

Figure 206. Loa Hatchery, Per Cent Change in Aquatic Invertebrate Concentration.

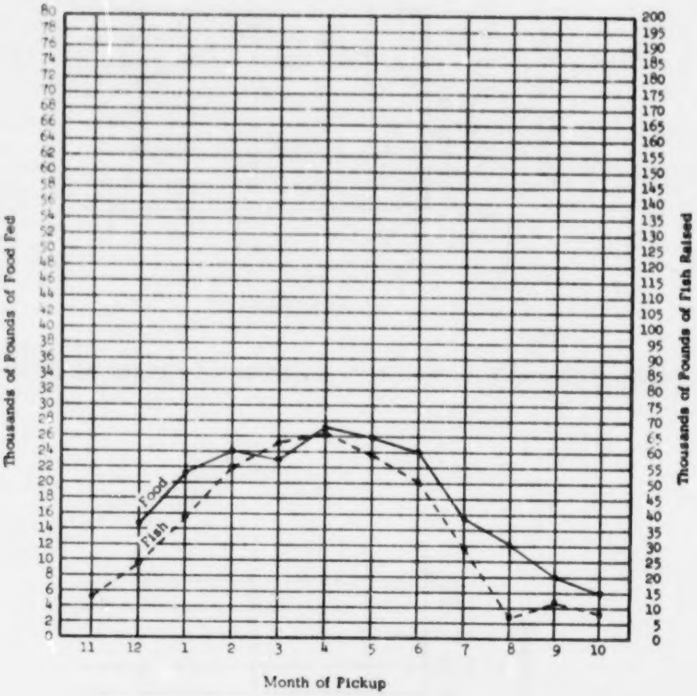

Figure 207. Loa Hatchery, Feed and Fish Fed During the Sampling Period.

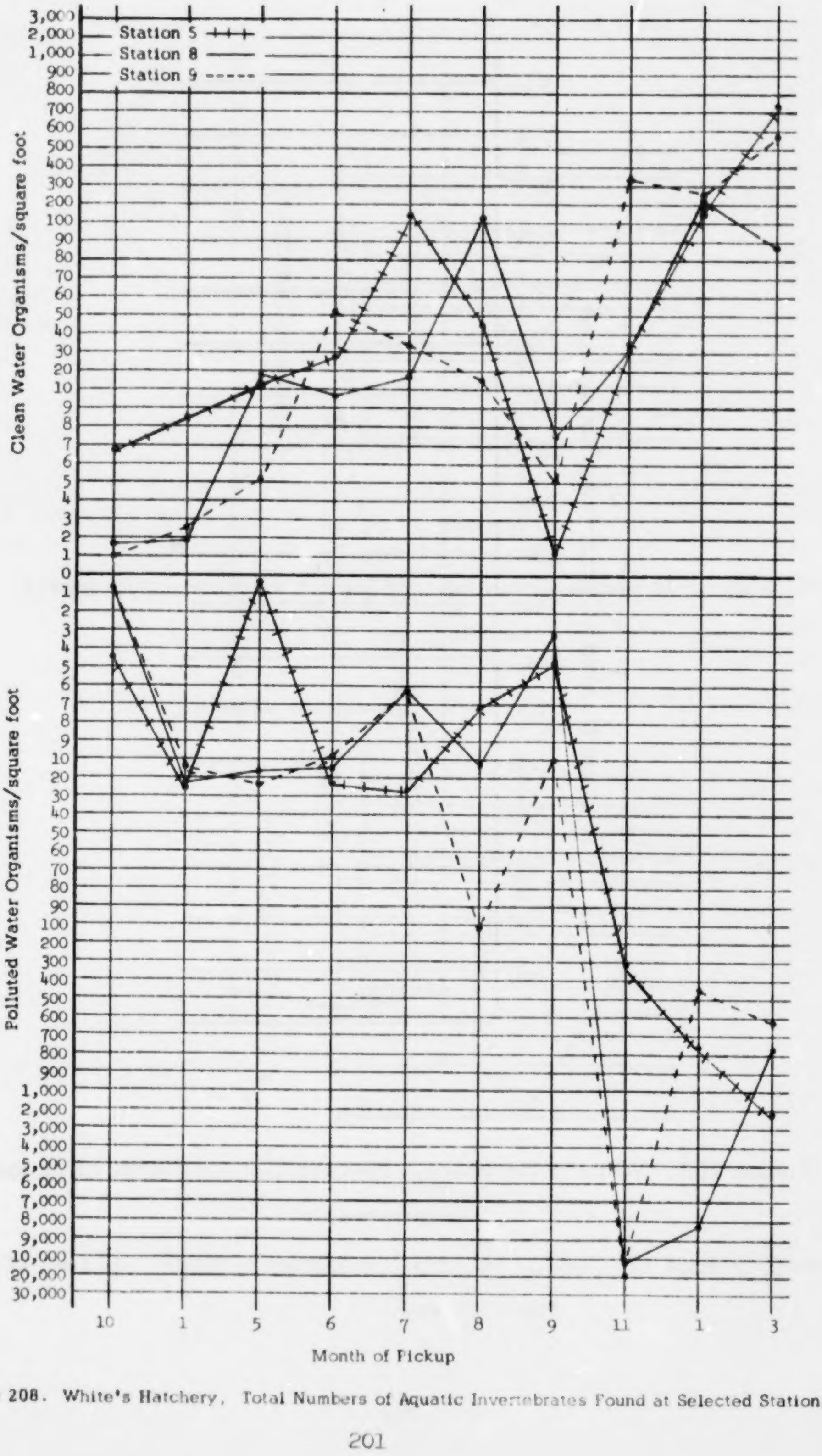

Figure 208. White's Hatchery, Total Numbers of Aquatic Invertebrates Found at Selected Stations.

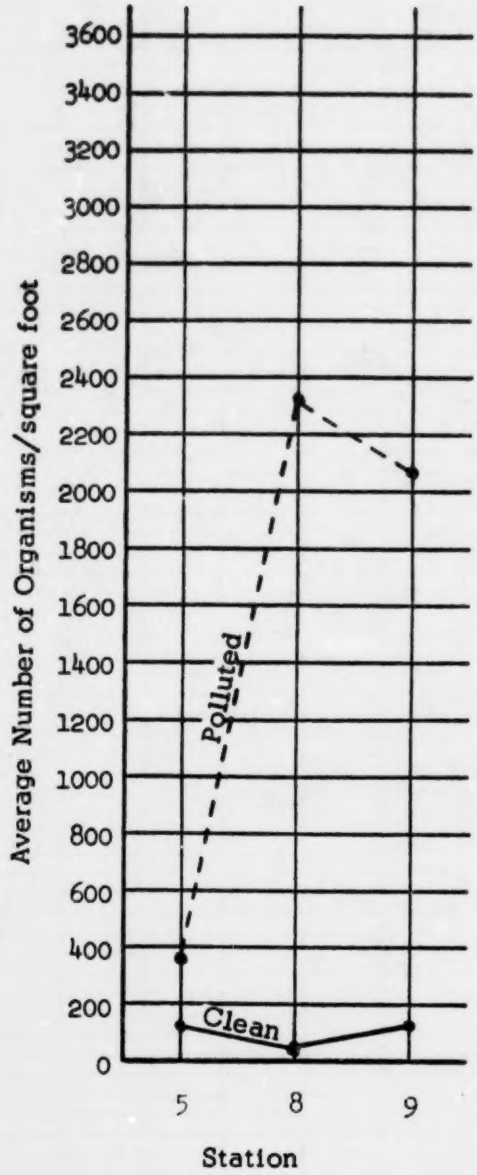

Figure 209. White's Hatchery, Average Concentration of Aquatic Invertebrates.

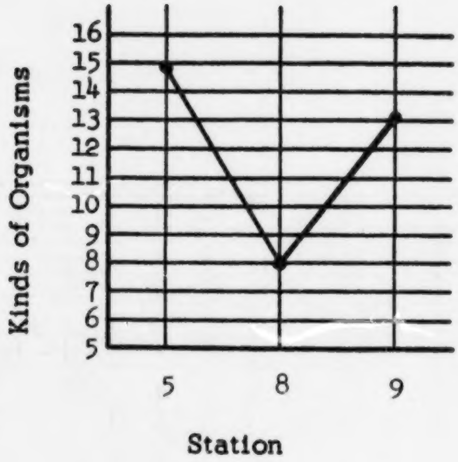

Figure 210. White's Hatchery, Average Number of Kinds at Selected Stations.

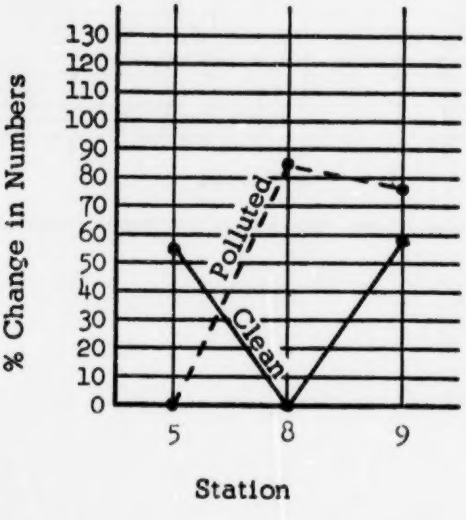

Figure 211. White's Hatchery, Per Cent Change in Aquatic Invertebrate Concentration.

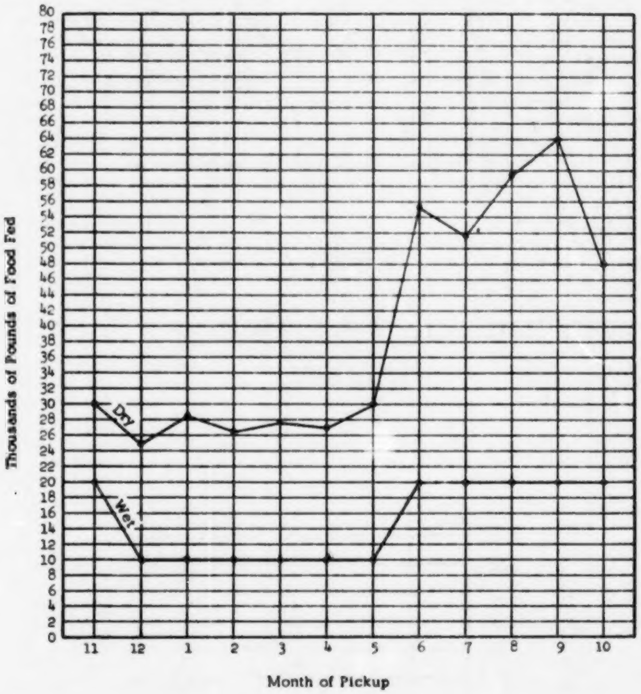

Figure 212. White's Hatchery, Wet and Dry Feed Fed During the Sampling Period.

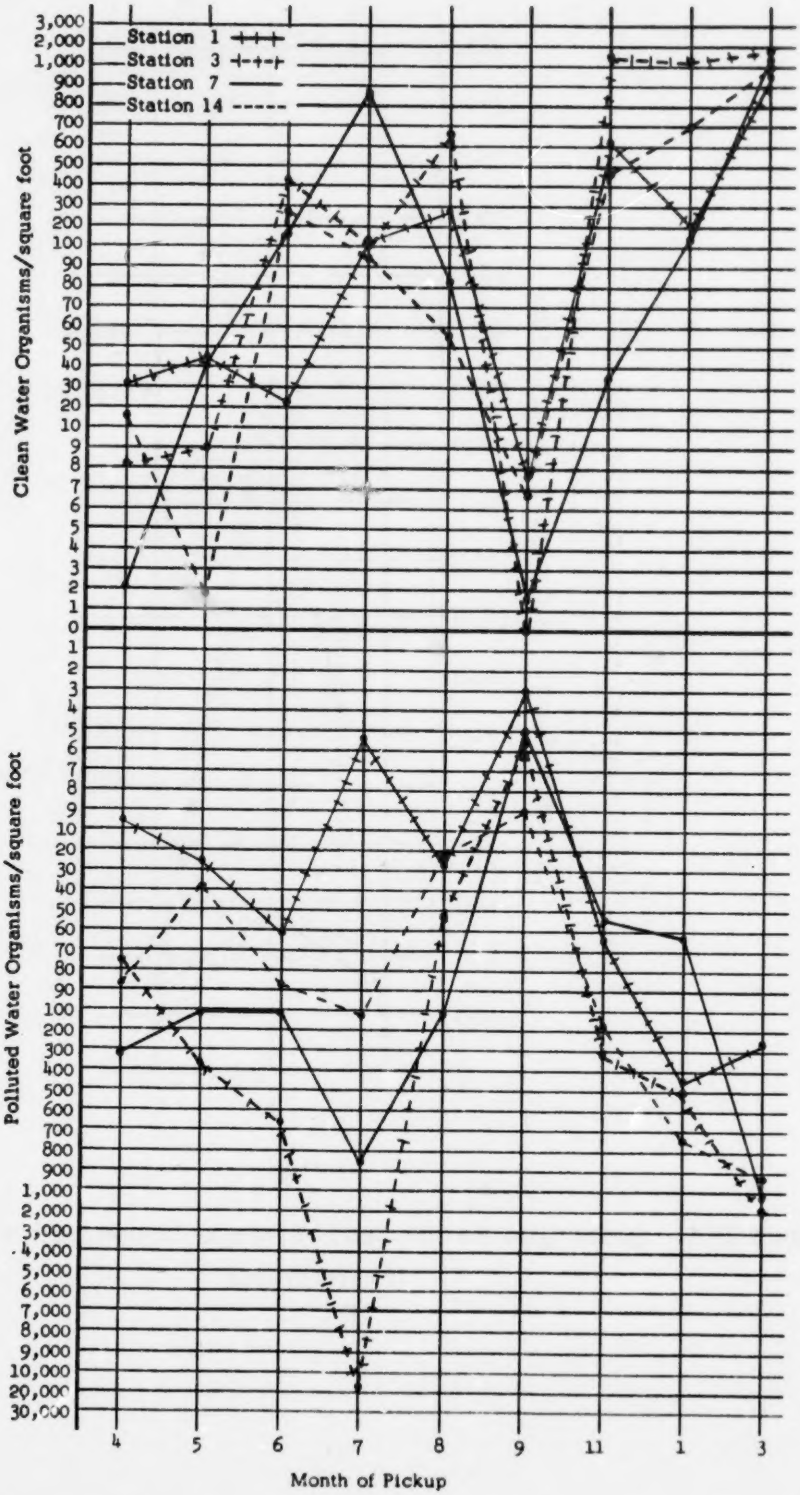

Figure 213. Springville Hatcheries, Total Number of Aquatic Invertebrates Found at Selected Stations.

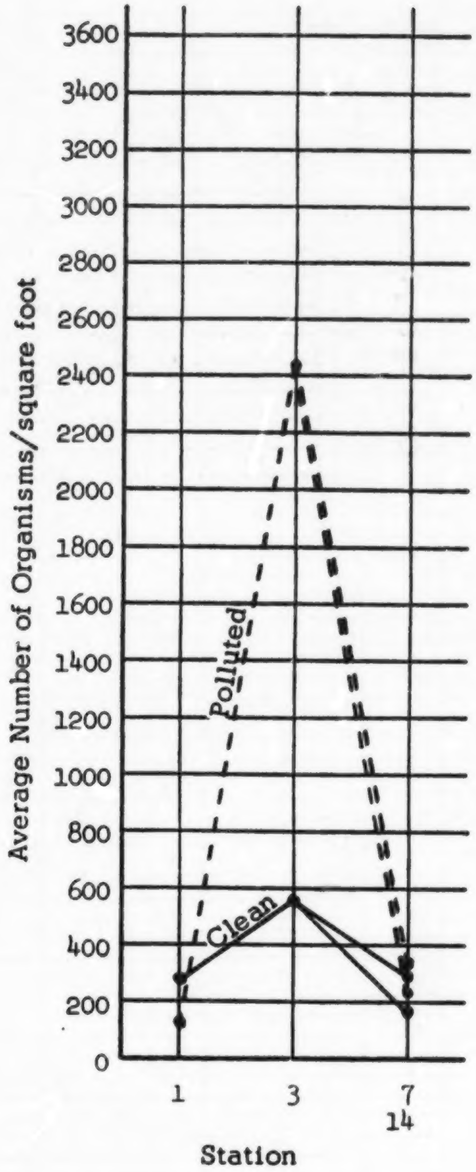

Figure 214. Springville Hatcheries, Average Concentration of Aquatic Invertebrates.

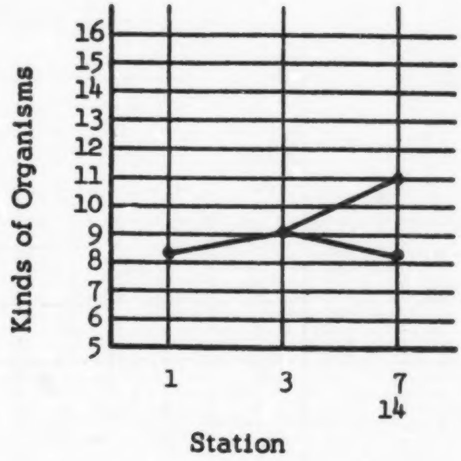

Figure 215. Springville Hatcheries, Average Number of Kinds at Selected Stations.

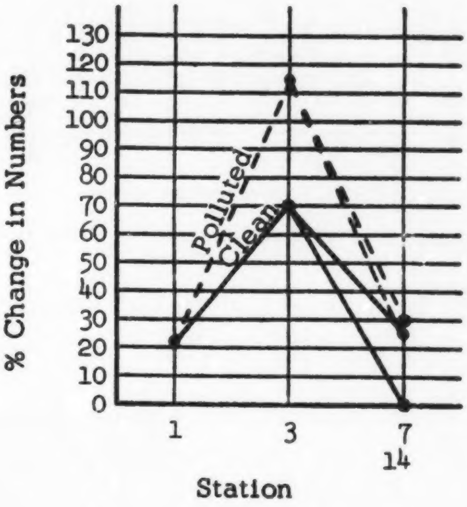

Figure 216. Springville Hatcheries, Per Cent Change in Aquatic Invertebrate Concentration.

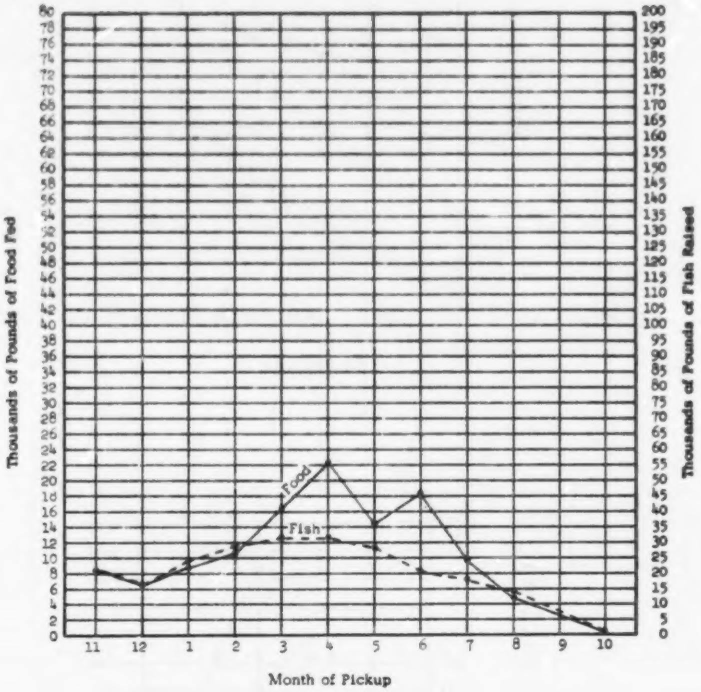

Figure 217. Springville Hatchery (State). Feed and Fish Fed During the Sampling Period.

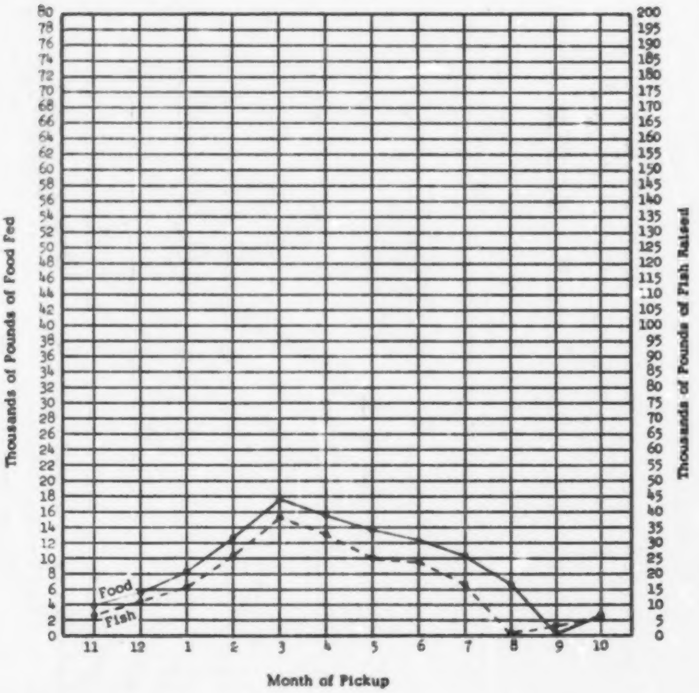

Figure 218. Springville Hatchery (Federal), Feed and Fish Fed During the Sampling Period.